GEC ALSTHOM

NEYRPIC

DIGITAL SPEED GOVERNOR FOR WATER TURBINES
DIGIPID 02

DESCRIPTIVE NOTE

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FOREWORD

It was in the French Alps, near GRENOBLE, that the hydroelectric energy - "Water Power" - was first developed during the 19th century, mainly under the impulse of ARISTIDE BERGES. Very soon after, the requirements of maintaining a constant frequency on the distribution networks revealed the importance and complexity of governing problems. At that time, this field was practically unexplored. Therefore, the water-power pioneers also opened the way to the governing systems by developing and experimenting the first theories and devising the first solutions from which so many applications have been derived in all sectors of industry.

NEYRPIC, a water-turbine manufacturer since 1854, set-up in GRENOBLE, contributed actively to all this work, combining its manufacturer's experience and thorough knowledge of the various mechanical, electrical and hydraulic parameters that are of major effect on the operation, flexibility and stability of the Units. Among the top international specialists in governing systems, the NEYRPIC's Engineers have always been in a first rank position and many of their inventions have found world applications. With the successive developments of turbine technology - resulting in increasingly higher outputs, improved efficiencies and smaller specific costs and leading to new types of machines to cope with more stringent and complex operating requirements - NEYRPIC has been designing, manufacturing, perfecting and testing the solutions proposed today to its worldwide customers.

More than 2,300 NEYRPIC governors, including over 800 of the electronic type, have been commissioned in various countries throughout the world. A great number of them are used on new or old turbines that were not manufactured by NEYRPIC.

Before 1910, NEYRPIC designed mechanical speed governors only, using belts as amplifiers ; next, hydromechanical amplifiers were developed, using water and later, oil. Since then, the technique of hydromechanical and then hydroelectrical technology has permanently been improved : the tachometer belt drive was replaced by a "pilot" permanent magnet generator, then by a static-frequency sensing device (by transformer). The 570 governor, the latest mechanical governor designed by NEYRPIC, is one of the best examples of the high degree of perfection attained in the field of hydromechanical governing.

Development of the electronic techniques has resulted in the multiplication and automation of the piloting functions and, consequently in the improvement in the control of turbine-generator Units.

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As from 1959, the technical teams of NEYRPIC have worked on electronic governing systems that offer strong advantages, mainly as concerns the flexibility of use and adaptation. So, in 1959 NEYRPIC built the continuous action RT 81 governor, then in 1966, the intermittent-action simplified RS 83 governor using the transistor technique and then, in 1969 the continuous action RAPID governor and derived from it, the intermittent action simplified RD 83 governor based on the operational amplifier technology, and finally, in 1977, the RAPID 77 governor.

In view of the industrial development of microprocessor digital technology, NEYRPIC has deemed it wise to use its numerous advantages for designing a governor with still higher performances, easier operation and maintenance and capable of interfacing with the most modern equipment of the hydraulic power stations (programmable controllers, computers). It has been materialized in the DIGIPID governor, dealt in this document.

It should be reminded that water turbine governing constitutes a whole system that must be treated as such. NEYRPIC has therefore studied governing problems as a whole, without separating the electronic field from the hydraulic field where technical innovations have also been made. Thanks to its great experience NEYRPIC is offering today rational and high quality governors for single or double regulation systems.

I - SPEED GOVERNING

1.1. INTRODUCTION

This Section recalls the essential functions of modern water-turbine governing , such as achieved by the electronic and hydraulic governing systems designed by NEYRPIC.

1.2. GENERAL OUTLINE OF AUTOMATIC GOVERNING

In a plant constituting the controlled system with automatic governing, the output value (regulated value) must be closest possible to the specified value (setting value) in spite of any disturbances.

This is obtained in the controlled system illustrated by the following governing loop :

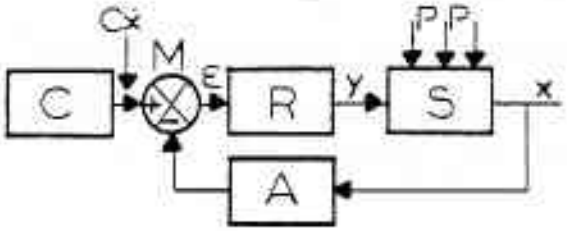

Fig.1 - Automatic governing loop

C = Setter

M = Summator

R = Regulating devices

Y = regulating value

S = Controlled system

P = Disturbing effects

X = Regulated value

A = Regulated-value measuring device (feedback)

ε = Governing deviation

The setting value (Cx) is compared in the summator (M) to that given by the device (A) measuring the regulated value (X). The difference (ε) between the two values - called governing deviation - generates the regulating value (Y) through the regulating devices (R) acting on the controlled system (S) until the regulated value (X) reaches its setting value (Cx) ; the governing deviation (ε) is then equal to zero.

The regulating devices (R) and the controlled system (S) constitute the direct system (control system). The sensing device (A) of the regulated value (measurement) and the summator (M) constitute the reaction or return system having a feedback action. The determining features of good governing are :

- precision and reliability under steady state operation

- stability and response promptness under transient conditions.

Since these two features are conflicting, optimization of the governing functions must be sought.

1.3. Turbine-generator Unit governing

The governing system comprises :

- a governor, i.e. electronic circuits arranged in a cabinet or cubicle, constituting the data centralizing "brain" and processing the control orders

- measuring devices that issue the feedback signals to the governor

- regulating devices that carry-out the orders issued by the governor (actuator, oil distributing valve, servomotor controlling the turbine water supply)

A water-turbine governor can include several governing loops, the most usual ones being as follows :

- frequency or Unit rotational speed loop (primary adjustment)

- Unit output loop (secondary adjustment)

The governor can also receive orders issued by network dispatching or level regulating systems.

Fig.2 illustrates the frequency and output governing loops for a turbine-generator Unit with output set-point.

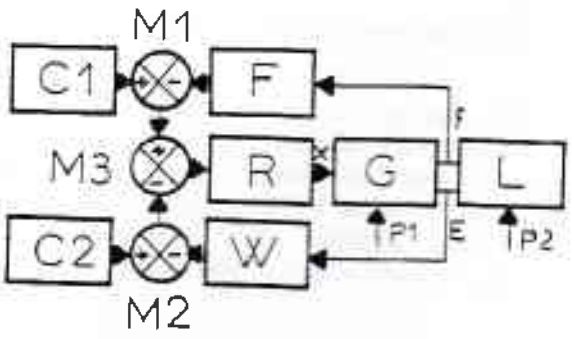

Fig.2. Frequency and output governing loops of a turbine-generator Unit

C1 = Frequency setter

C2 = Output setter

M1,M2,M3 = Summators

R = Turbine regulating devices

G = Turbine-generator Unit

E = Unit output

f = Unit frequency

W = Unit output measurement

F = Unit frequency measurement

P1 = Disturbance due to head variation

P2 = Disturbance due to load variation

L = Network

A few conventional examples are given below for illustrating the functions of the frequency and output governing loops.

1.3.1. When a Unit is not connected to the network, its power output is zero ; only the frequency governing loop is operating. The Unit frequency must rapidly be increased or reduced to the network frequency value in order to permit Unit connection during start-up or after load rejection.

1.3.2. When the generator is connected to a network of much greater power than its output, the frequency is imposed by the network. The output governing loop then allows controlling the Unit output. The frequency and output are interconnected since under steady state conditions the signal issued by Summator M3 (fig.2) is zero. This implies that the signals of the frequency and output systems are zero or equal in absolute value and of opposite sign.
Fig.3 shows the theoretical characteristic relating the frequency to the output under steady state conditions. The slope of this curve enables to define the frequency/output permanent speed droop

$$bp = \frac{\Delta f/fo}{\Delta E/Eo}$$

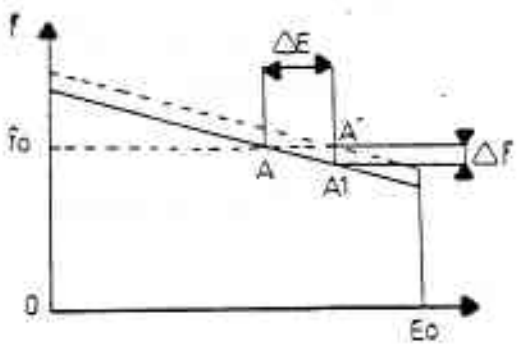

Fig.3 - Frequency/output characteristics of the frequency and output governing loops under steady state conditions

f = Unit frequency

fo = rated frequency

Δf = frequency deviation corresponding to output variation ΔE

E = Unit output

Eo = rated output

ΔE = output variation

b_p = permanent speed droop

The lower the permanent speed droop, the greater participation of the Unit in network frequency control is required. Any variation of the output setting results in a shifting of the permanent speed droop curve, the operating point moving from A to A'.

An opening permanent speed droop can also be defined by replacing the output by the turbine gate opening.

1.3.3. When the network frequency must be controlled by the Unit alone, the frequency setting system operates and tends to maintain the Unit output equal to the network input. Under steady state conditions, the network frequency is equal to the frequency setting and the adjustment is then of the non-static type ($b_p = 0$)

1.4. GOVERNING BY P.I.D. ACTION (Proportional, integral and derivative)

The meaning of P.I.D. governing functions and their combinations are briefly recalled below :

- proportional (P) action governors ensure a proportionality between the regulating value and the setting error (frequency deviation for instance). With such type of governor and a fixed setting value, there is a permanent error that depends on the Unit output, resulting in frequency adjustment inaccuracy. The regulated values depend both on the setting value and on the regulating value.

- for eliminating this drawback, an integral (I) action cancels the error under steady state conditions. This action adds to the term proportional to the governing deviation another term that is proportional to the integral of this deviation in terms of the time. The regulating value being constant under steady state conditions, the integral is constant too ; the setting error is thus cancelled.

  This mode of action (I) eliminates the inaccuracy under steady state conditions but introduces a phase shift unfavourable to the system stability.

- in order to make-up for this phase shift due to the integral action, a derivative (D) action is introduced (anticipation effect or phase advance) by adding to the term proportional to the setting deviation a component proportional to the derivative in terms of time, of the regulated value. For frequency governing, the derivative action is proportional to the angular acceleration of the Unit. The derivative action improves the system stability

- In case of high-amplitude disturbances, P.I.D. actions are not sufficient. NEYRPIC has therefore developed a special algorithm (Neyrpic-patented) that ensures stability even in the non-linear operating range.

All the above solutions have been combined when designing the DIGIPID governor.

2. DESIGN OF DIGIPID GOVERNOR

2.1. STRUCTURE

The basic functional structure of the DIGIPID governor is illustrated below :

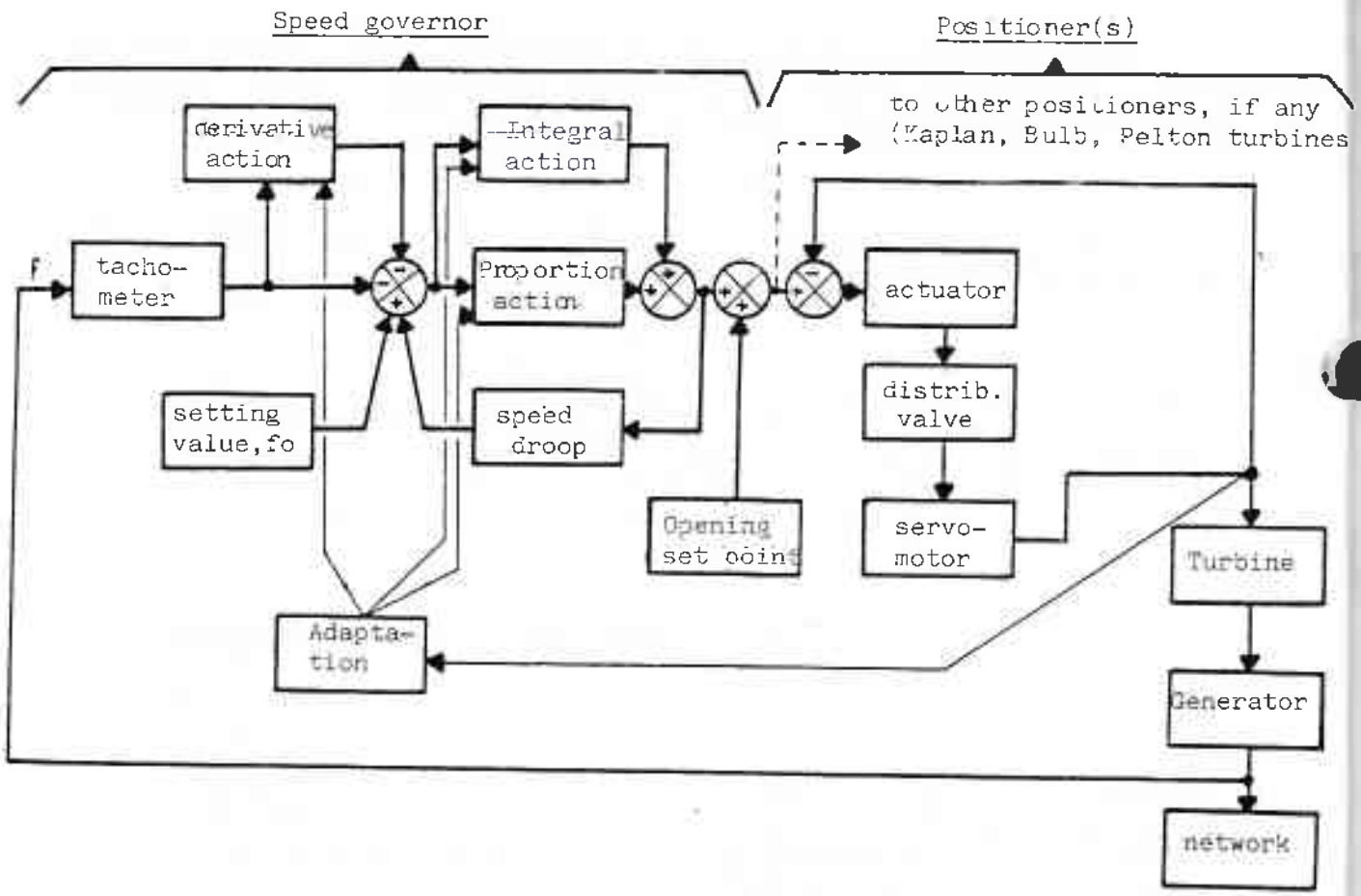

Fig.4 - DIGIPID functional diagram

This structure comprises :

- a speed governor stage that processes the position set-point in terms of the Unit speed and of the opening set-point through a PID governor

- a power stage that positions the turbine regulating device by means of a controlled hydraulic system (actuator, distributing valve, servomotor).

While this positioning loop is a simple one for Francis turbines it may comprise as many hydraulic systems as the number of control devices for the other types of turbines.

This design permits to dissociate the optimization of the speed governing loop from the optimization of the positioner(s).

2.2. OPERATING DIAGRAM

Fig.5, page 10, illustrates the general operating diagram of the DIGIPID governor ; the standard functions, comon to all DIGIPID governors, are shown in solid lines and optional functions are shown in dotted lines.

It should be noted that the DIGIPID being a programmed digital governor, contrarily to the governors of the previous generation, this functional structure does not correspond to a physical structure where each function is associated to an electronic board.

The following functional assemblies can be shown on this diagram:

- speed governor itself, with P.I.D. actions ("tachometer-accelerometer" and "P.I. governor" blocks)

- a parameter-adapting structure that ensures optimum operation independently of the generated power

- the electrohydraulic positioner ("copying system" block) comprising:

  . electronic power amplifier controlling the electrohydraulic transducer

  . NEYRPIC electrohydraulic transducer (or actuator)

  . main distributing valve controlled by the actuator, fitted at the upper part, with a displacement transducer for the main distributing valve feedback.

  . the servomotor, with position feedback, controlling the turbine regulating device

- the opening limiter that issues starting set-points as well as a set-point, after connection to the network (the set-point can remotely be controlled)

- the speed (before connection to network) and load (after connection) setter :

  The set point can be controlled locally or remotely (logic orders or analogic remote-setting)

- the manual control(s) of the turbine regulating devices , located on the front face : speed and load adjustment is then entirely disconnected

Moreover, the DIGIPID governor supplies a number of data to the outside, either logic (speed or output limiting values, setter status..) or analogic (remote indications).

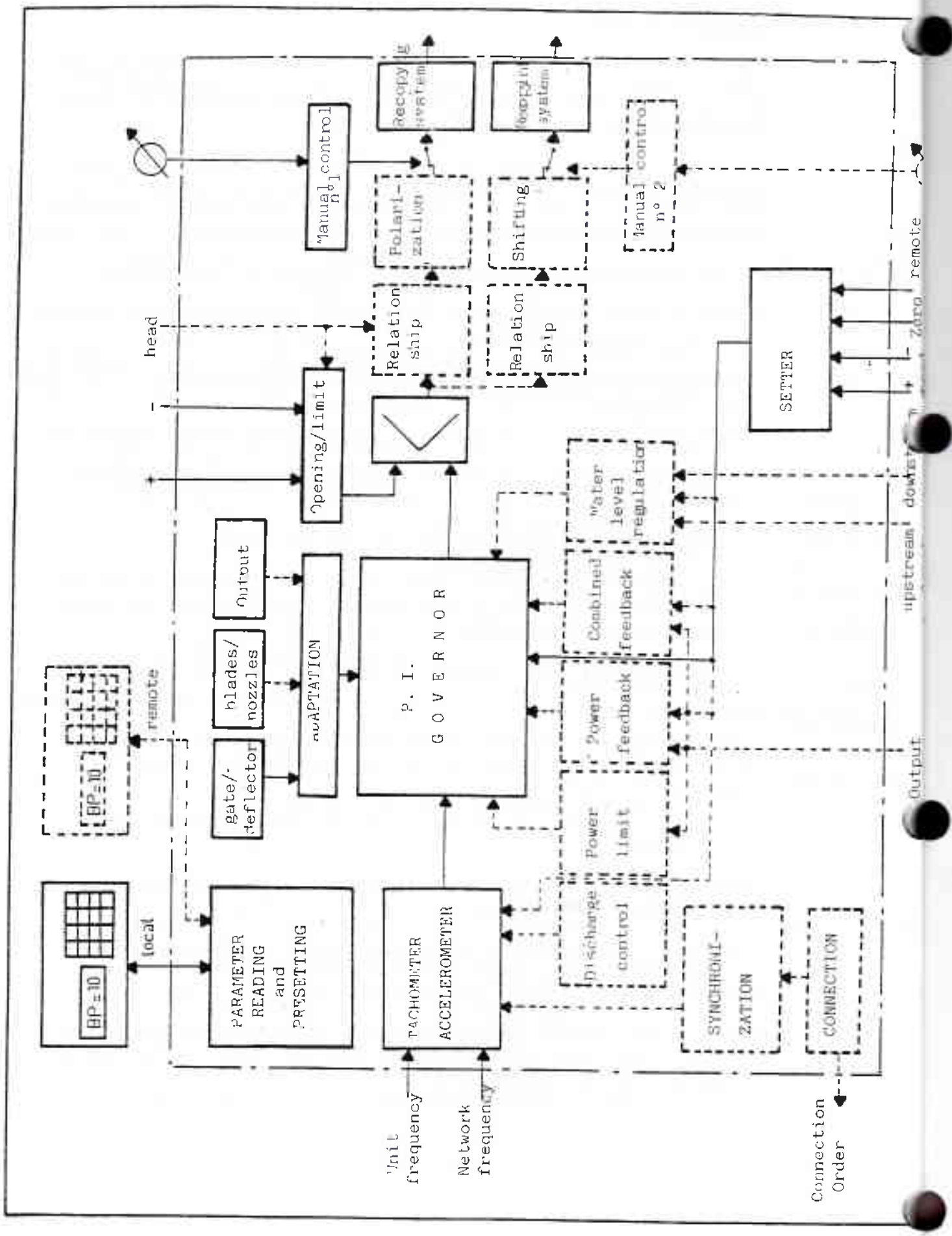

Fig.5 - General operating diagram of DIGIPID governor

In the standard design, the governor is fed from the permanent d.c. power supply of the power station ; this permits Unit re-starting under all circumstances. Power supply from other sources is proposed in option.

2.3. TRANSFER FUNCTIONS

The DIGIPID structure comprises two separate blocks arranged in cascade :

- electronic speed governor itself, with a transfer function R (p)
- electrohydraulic positioner, with a transfer function T (p)

The transfer function, S (p), of the DIGIPID is given by S (p) = R (p) x T (p)

2.3.1. Transfer function of speed governor - linear operating conditions (small displacements)

This transfer function is shown below :

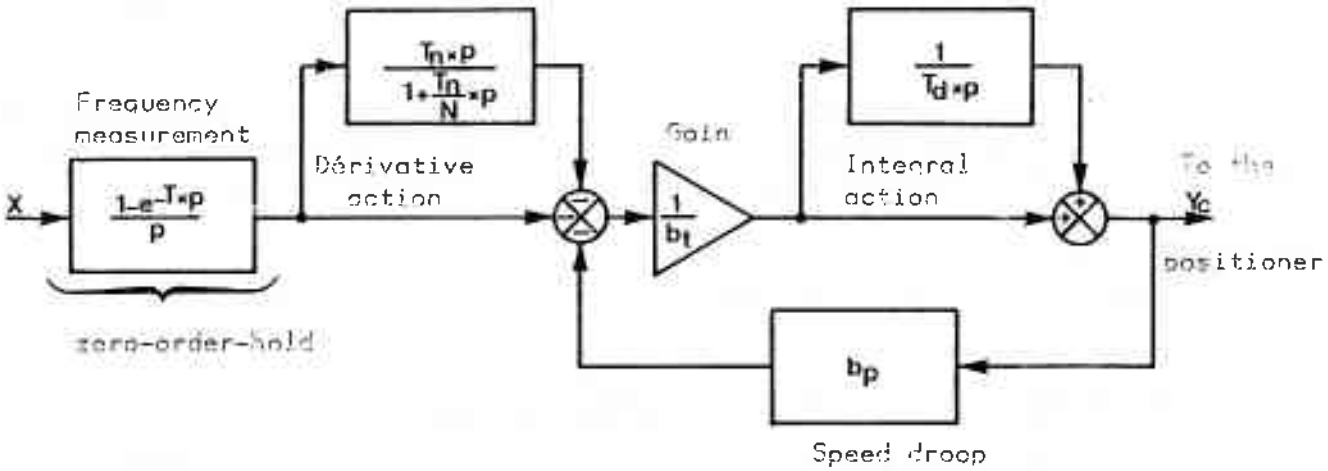

FIG : 6

x = relative speed deviation $\frac{\Delta n}{nN}$

yc = relative displacement order to servomotor

Tn = diversion time constant

N = limiting factor of diverter band-pass

T = sampling period

$\frac{1}{bt}$ = governor gain

Td = time constant of integral action

bp = per manent speed droop

p = LAPLACE variable

The structure is that of a P.I.D. governor (Proportional, Integral and Derivative action governor) - parallel /series - with one advantage being that the phase-advance derivative term participates in the de-saturation of the integral action.

The speed droop term, bp, that has not a zero value during load-setting operation, renders proportional the P.I.D. governor that is non-static during pure speed setting operation

The transfer function, R (p), of the speed governor with speed droop, writes down as follows, according to the previous block diagram :

$$R(p) = \frac{1-e^{-Tp}}{p} \times \frac{1 + T_n \left(1 + \frac{1}{N}\right)p}{1 + \frac{Tn}{N} p} \times \frac{1}{b_p} \times \frac{1 + T_d\, p}{1 + \frac{b_p + b_t}{b_p} T_d\, p}$$

If speed droop is equal to zero (bp = 0), the sampling period T is sufficiently small and the diverter is perfect ($N = \infty$), the conventional transfer function of a P.I.D. governor is obtained, viz. :

$$R\,(p) = \frac{-1}{b_t} \left(\frac{T_n + T_d}{T_d} + \frac{1}{T_d p} + T_n\, p \right)$$

2.3.2. Transfer function of electrohydraulic positioner

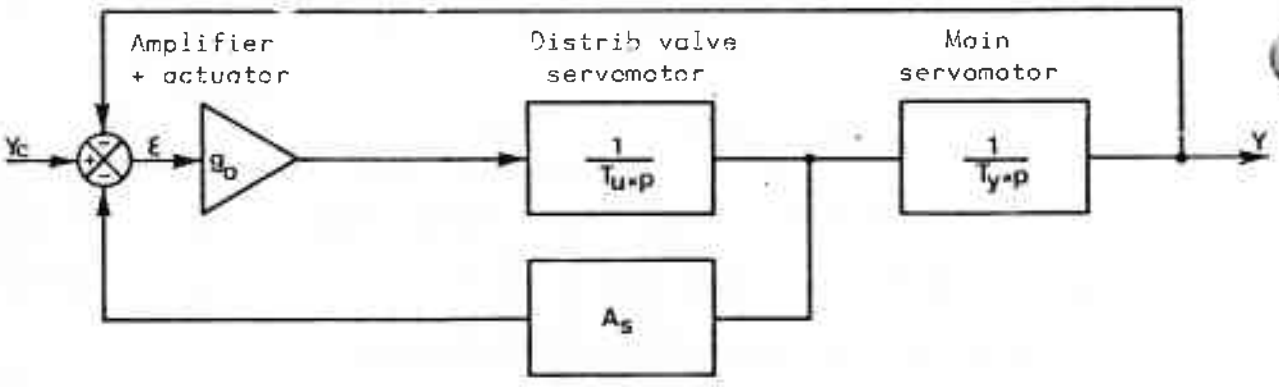

FIG : 7

yc = relative displacement set-point of main servomotor

$= \frac{\Delta Yc}{YM}$

y = relative displacement of main servomotor $= \frac{\Delta Y}{YM}$

u = relative displacement of main distributing valve spool

$= \frac{\Delta u}{uM}$

g_o = proportional gain between the actuator valve spool rising and the error $\varepsilon = y_c - u - As.\ u$

T_u = time required for the main distributing valve spool to perform its nominal travel in relation to its equilibrium position, when no flow restrictors are provided

T_y = time required for the main servomotor to perform a full stroke (corresponding to nominal travel of main distributing valve spool) in relation to its equilibrium position, when no diaphragms are provided for adjusting the operating time

A_s = position feedback coefficient of the main distributing valve spool

Comment : T_u and T_y are dependent on the piloted volume displacement and operating forces and also on the shape of the pilot distributing valve spool.

The transfer function, T (p), of the electrohydraulic positioner writes (according to the above diagram) :

$$T(p) = \frac{y}{y_c} = \frac{1}{1 + A_s\ T_y\ p + \frac{T_u\ T_y}{g_o}\ p^2}$$

The second-order denominator can be identified to the conventional canonical form :

$$\frac{p^2}{\omega_c^{\,2}} + \frac{2\varphi p}{\omega_c} + 1, \quad \text{where } \omega_c \text{ is the natural angular frequency}$$

φ is the attenuation factor

After identification :

$$\omega_c = \sqrt{\frac{g_o}{T_u\ T_y}} \qquad \varphi = \frac{A_s}{2}\sqrt{\frac{g_o\ T_y}{T_u}}$$

T_u and T_y being determined at the design stage, the pass-band can therefore be adjusted over a given range by the electronic gain that modifies g_o .

Attenuation is adjusted by the A_s term. For obtaining the critical attenuation $\varphi = \frac{\sqrt{2}}{2}$, A_s should meet the following relationship :

$$A_s^{\,2} = \frac{2\ T_u}{g_o\ T_y}$$

It must therefore be noted that contrarily to the speed governing loop, the position loop is fully analogic.

2.4. GENERAL DESIGN OF DIGIPID SOFTWARE

The DIGIPID software has been designed to meet the following two essential criteria :

- quick performance thanks to a real-time structure
- safety

2.4.1. Real-time structure

The DIGIPID governor is fitted with a sophisticated multi-tasks real-time structure similar to that developed by professional minicomputer manufacturers.

Each basic function (such as tacho-accelerometer, P.I. regulation) is constituted in an autonomous task having the following characteristics :

- periodicity : the accurate periodicity of sampling is a vital factor of a digital governor stability
- priority : depending on its priority, a task can interrupt another task under way or, on the contrary, be interrupted by the latter
  The priority is representative, in a first approximation, of the importance of a task regarding the overall duty of the governor

The performance of all tasks, and in particular, their starting-up at given instants, is controlled by a real time monitor, according to :

- the "tops" of a real time quartz clock
- interrupts closure, writing of a character with the keyboard...)

2.4.2. Safety

During normal operation of the governor, an auto-test program ascertains of correction operation of its main components (central processing unit, arithmetic computing processor, memories, analog inputs, etc..) and takes the necessary steps in case of fault (switching to degraded operation or complete shutdown of the Unit)

Also, a supervising circuit, of the "watchdog" type, checks the sofware for correct operation and causes the Unit to shut-down in case of fault.

3. DESCRIPTION OF THE ELECTRONIC EQUIPMENT

3.1. TECHNOLOGY

The DIGIPID governor incorporates all the capabilities offered by the modern-microprocessor technology.

- Microprocessor joined to a floating point coprocessor in order to insure hight performance calculations

- EEPROM : alterable but non-volatile memory (even in case of power failure) for parameter storage. This memory does not need any backing battery which would impair its reliability

- PROM : permanent memory for program storage

- HCMOS logic circuits that ensure quick action combined to low consumption

All these features have permitted to design the DIGIPID rack with a compact configuration, rugged construction and reliable system. It is available as a 19" 4 U standard cabinet-rack.

In spite of the overall compactness, the plug-in-board architecture associated to excellent access provides for very easy maintenance (on-line testing is possible).

3.2. MAIN ADVANTAGES OF THE DIGIPID GOVERNOR

The DIGIPID governor meets the requirements of international bid specifications and complies, in particular, with the 63850 Standard for programmable controllers.

It is fed from the voltage issued by the supply-plate (+ 24 VD, ± 15V, 5V). Power inlet to the rack is through a 19-pin connector (J35). This power supply is carefully protected to prevent interferences from propagating into the governor internal circuits.

Frequency measurement through voltage transformers is unaffected by harmonic distorsion and driving voltage level (1 to 100% of rated voltage).

The rotor residual magnetism is adequate for giving the minimum voltage required when the generator is not energized. (Rack inlet through a 7-pin connector (J36)).

Analog processing is limited to analog-to-digital conversions for input and to digital-to-analog conversions for output, shifts induced by temperature or voltage variations being thus negligible.

The parameters - fully-numerically programmed - having accurate values the governor behaviour is very close to the shop simulations made at the design stage.

The improvement of the governing system, developed by NEYRPIC, allows stability during high variations on critical isolated grids.

Furthermore, numerous auto-test functions built-into the DIGIPID ensure optimum safety of the piloted system.

3.3. General description

The DIGIPID electronic equipment comprises : (see Sketch N5)

- a card-container in two sectors :

  . a "digital" sector accomodating all boards directly connected to the microprocessor bus; this sector is located on the left-hand side, when looking at the governor front face. It contains :

		Pattern 2	Pattern 3
. CPU	mark F47.	PC GES	PC GES
. memory	mark F46.	PC MEM	PC 460
. arithmetic calcul.processor	mark F48.	PC CALC	
. tachometer	mark F45.	PC 389	PC 389
. I/O, D/A and A/D convers.board	mark F49	PC 342	PC 342
. logic input/output interface	mark F52	PC 486	PC 486
. optional-card reserved spaces			
. RS422 serial communic.to outside	mark F50	PC SIO	PC SIO
. D/A output conversion board	mark F51	PC 343	PC 343

  . an "analog" sector, on the right-hand side, containing :

		Pattern 2 / Pattern 3		
. one or two positioners	mark F42	PC 380	or	PC 403
. one or two power amplifiers	mark F40	PC 382		
. logic I/S boards	mark F41	PC 402		
. input galvanic isolations	mark F38	PC 377	or	PC 504/0
. 4-20 mA outputs, if any	mark F43	PC 376	or	PC 504/1

NOTE :

Depending on the options selected : digital positioner, analog isolating interface, actuator type, number of I/O... the number and location of these analog boards may be modified.

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- a board located in the rear part (PC 406 , mark F04) which monitors the power supplies and gathers the faults of any origin

- a rear face (mark F03) hinged at the lower part, bearing all linking connectors to the outside. All connectors are provided with a plug-in discrimination system which avoids any mistake when reconnecting the DIGIPID rack (see Sketch N6)

- a front face (mark F02), also hinged at the lower part, giving access to the boards and test-points (see Sketch N7). It is fitted with :

  . 3 pilot lights :

    - major faults (COMPLETE SHUTDOWN OF UNIT)
    - minor faults (DEGRADED OPERATION OF GOVERNING SYSTEM)
    - power supply ON

  . a "maintenance" key that permits to start an auto-test programme or to reset the DIGIPID programme

  . two identical hand-control blocks (one block per turbine regulating device) comprising :

    - a "hand-control" pilot light with test button

    - a potentiometer for set-point adjustment

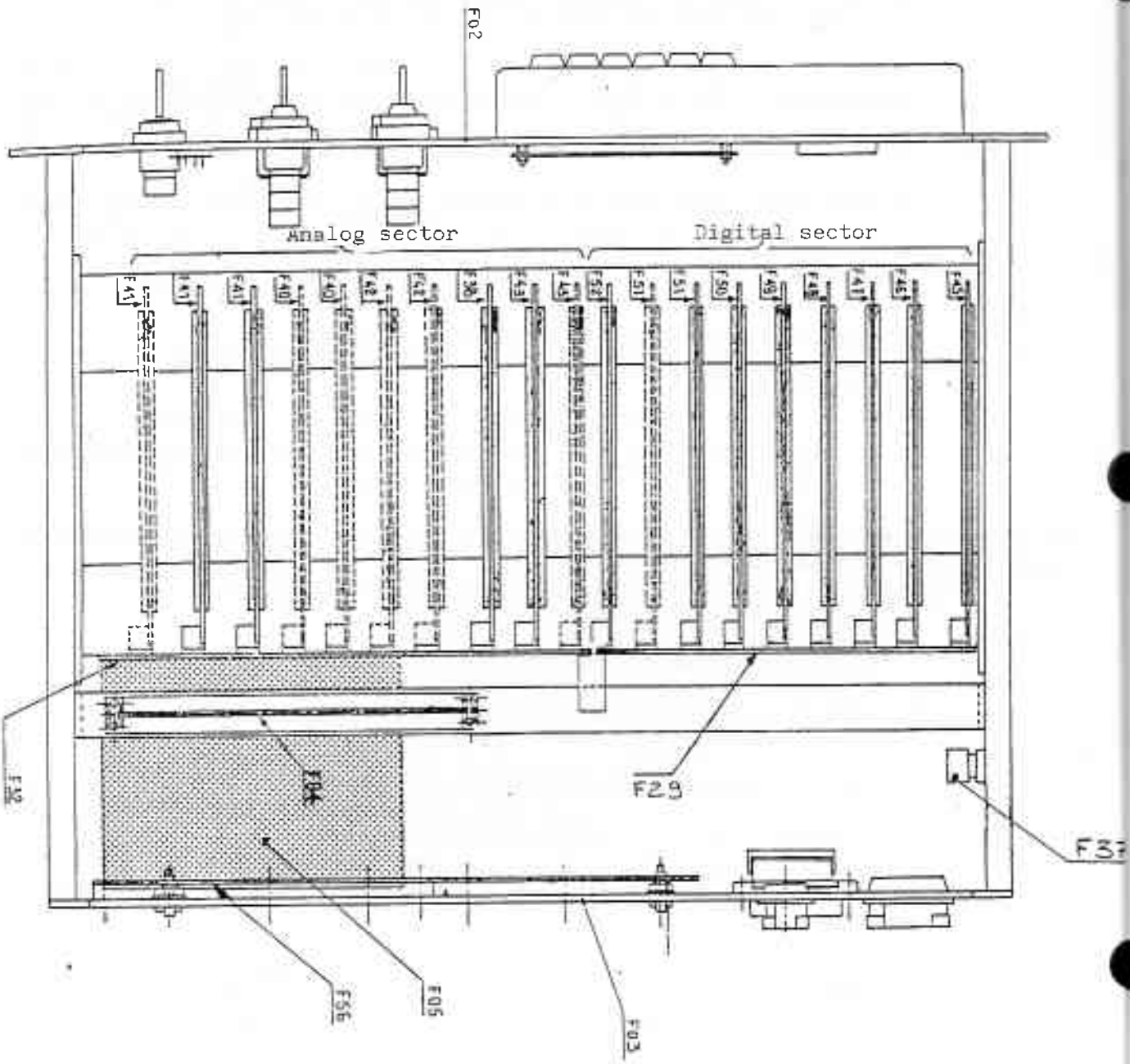
    - a manual/automatic selector (see Sketch N8)

  . a general-purpose case comprising :

    - a display unit : 16 alphanumeric characters

    - a keyboard : 10 numeric keys, 8 function keys and control-keys

FRONT FACE SIDE



CABINET - TOP VIEW

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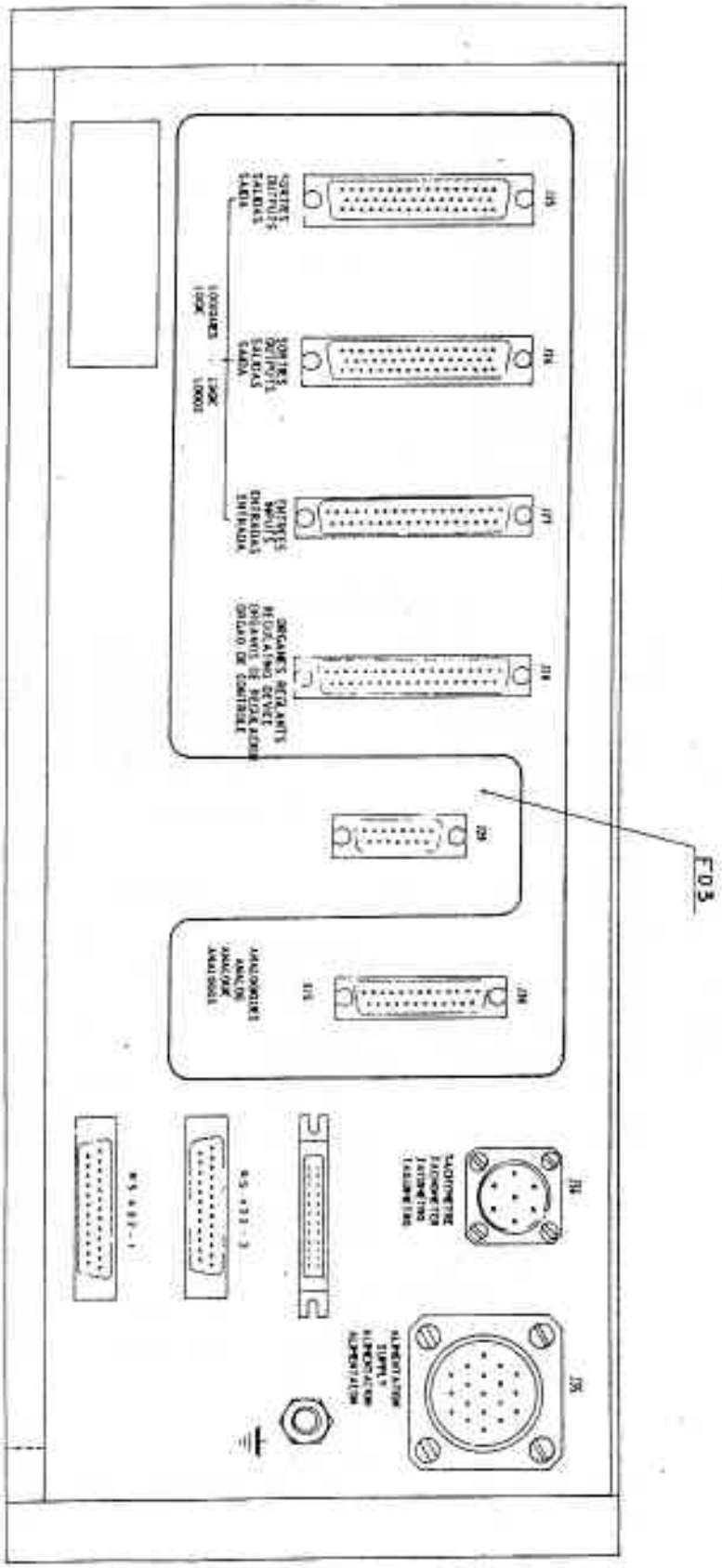
	VISE PAR		PLAN	SKETCH 5	PLAN		
	DATE						



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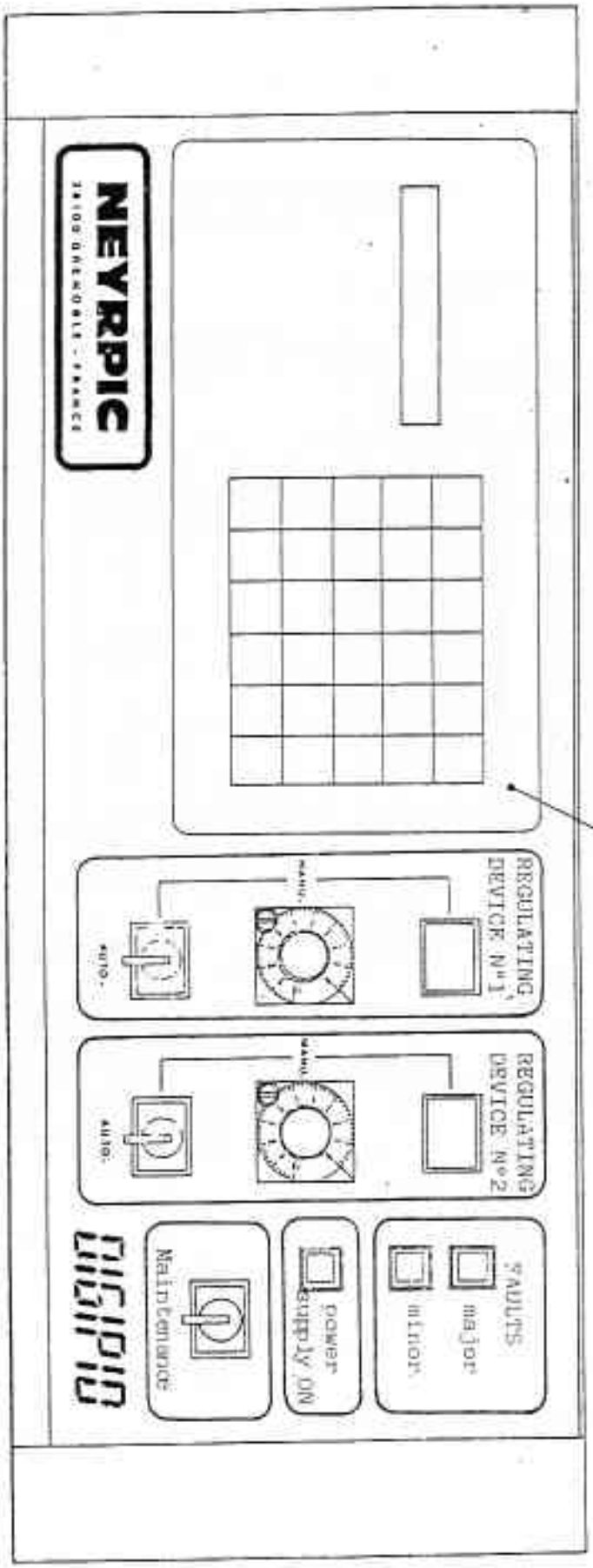

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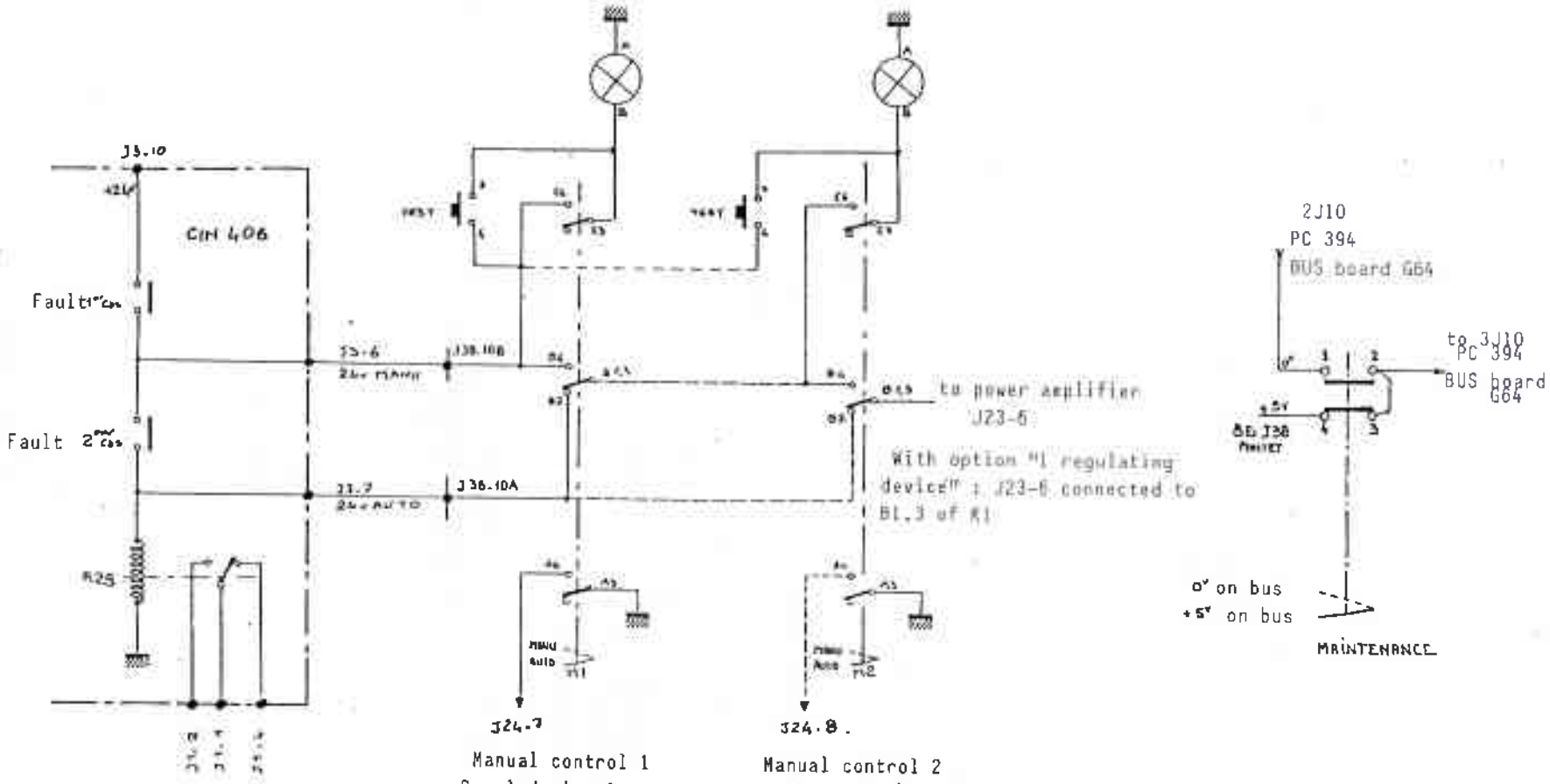


FAULT - 1st case

- Fault +15V
- Fault -15V
- fault POSITIONER 1
- fault POSITIONER 2
- fault POSITIONNER EXTENSION

FAULT - 2nd case

- fault +12V
- fault -12V
- fault +5V
- fault SOFT

K1 and K2 are shown on AUTO control position
Relays are shown with fault

MODIFICATIONS

DIGIPID

FRONT FACE

SKETCH

NEYRPIC

DESSINE PAR

VERIFIE PAR

Folio

3.4. ELECTRONIC BOARDS

SIMPLE EUROBOARD format.

The boards of the "digital" sector are designed with a 96-point connector to DIN 41612 and those of the "analog" sector with a 32-point connector to DIN 41612.

3.4.1. Bus G64/G96 - PC 394

This bus is used for communication between CPU board, memory board, digital to analog and analog to digital conversion boards, tachometer board and logical inputs-outputs to internal boards.

Each board is identified by its address; therefore, it may have any position on the BUS but due to (INTER-BOARD) connections they have been given a specific position . See sketch N5

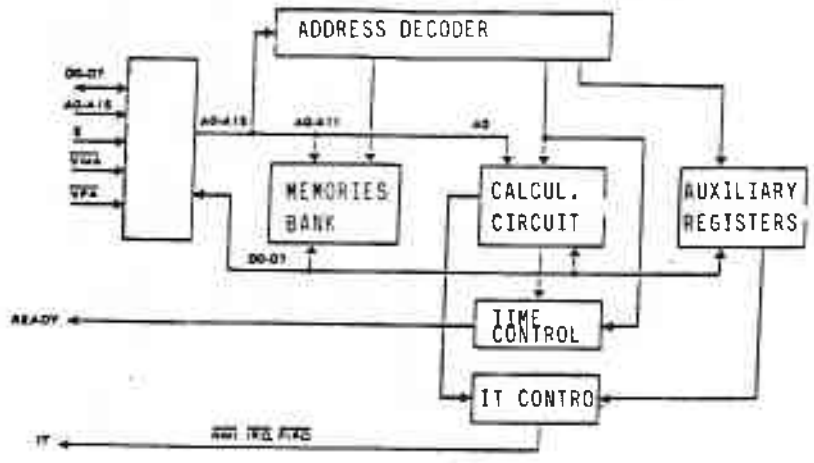
3.4.2. SBS4 board

It includes : Microprocessor
- (2 PROM + 1 RAM (Pattern 3)
- (3 PROM (Pattern 2)
- RS 232 interface
- Watchdog
- DATA buffer + 1 adress and control buffer

This board performs ordinary calculations and handles the transfers of information, instruction codes, data, timings..

3.4.3. CALC board

The CPU transmits the data of the calculation to be made and receives the results.
- Arithmetic processor, performs floating point calculations.



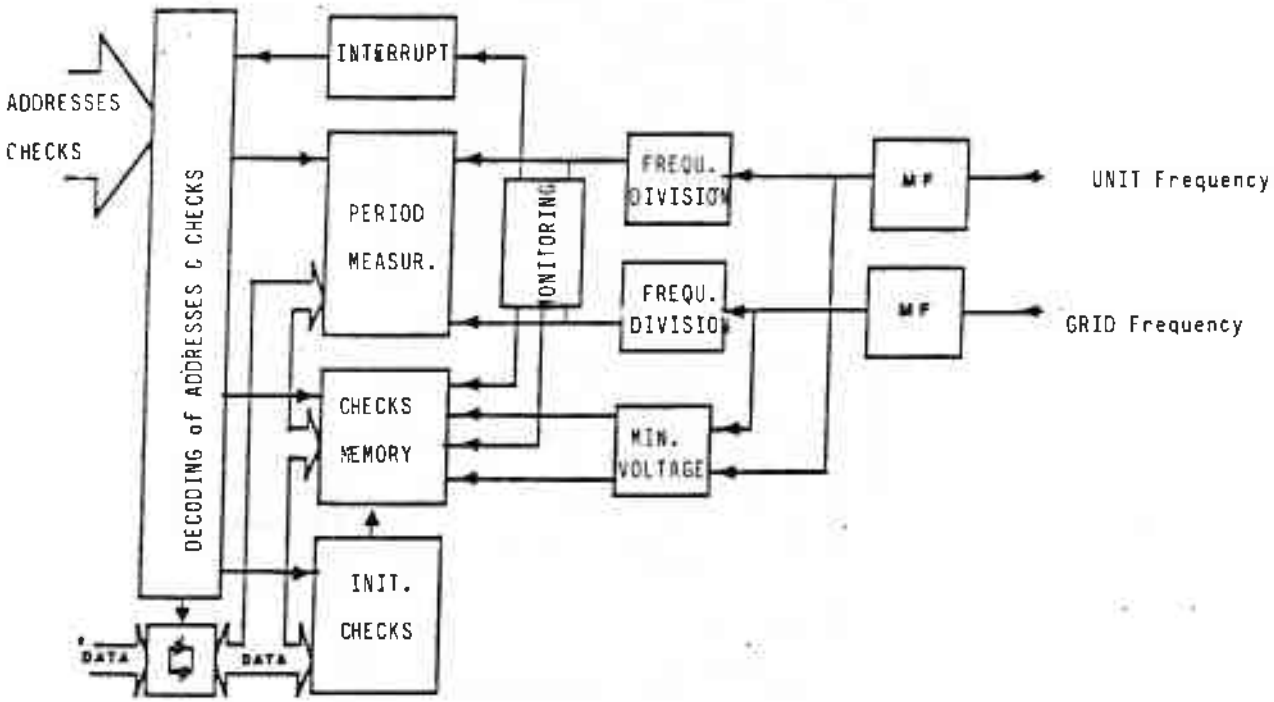
EPS-CALC : : Arithmetic calculation module

3.4.4. MEM BOARD

These EEPROM boards have a capacity of 32K octets.
Other types of memories are compatible and sub-divided into two 16K octet pages, or 8 memories of 2K each.

3.4.5. TAC-HTR BOARD - PC 389

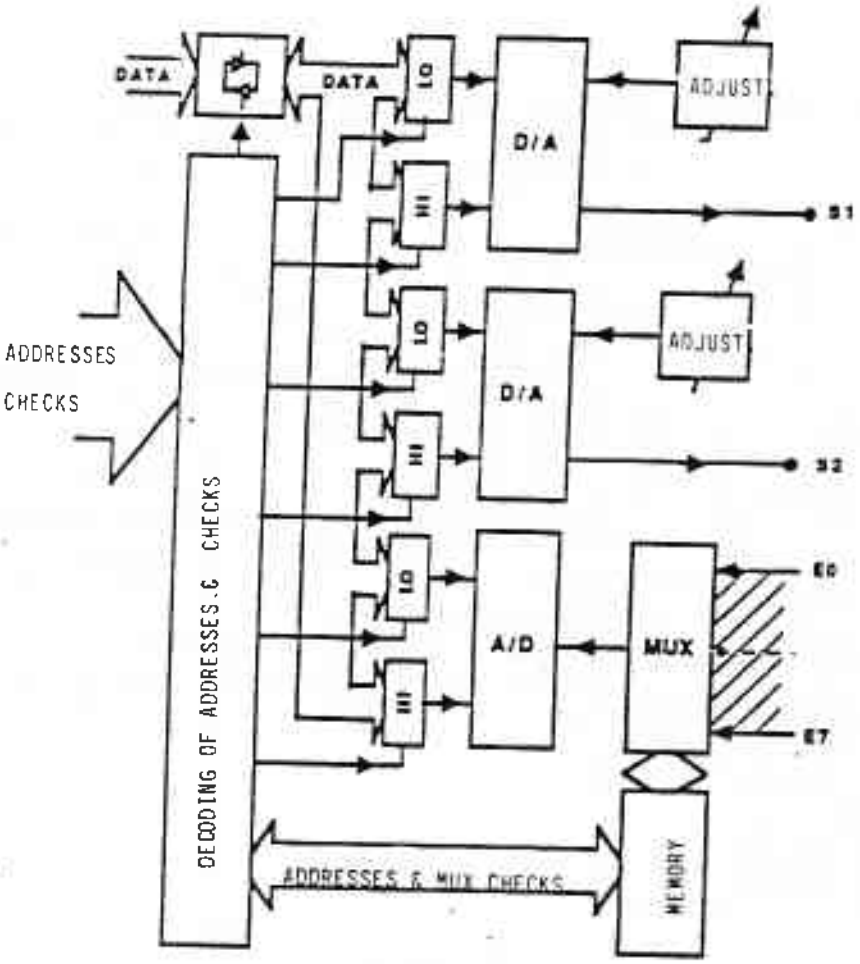
It measures the Unit and grid period (measurement based on Crystal frequency).
It monitors the grid voltage.
It checks whether measurement is effective.



TAC-HTR BOARD

3.4.6. MIADA BOARD - PC N° 342

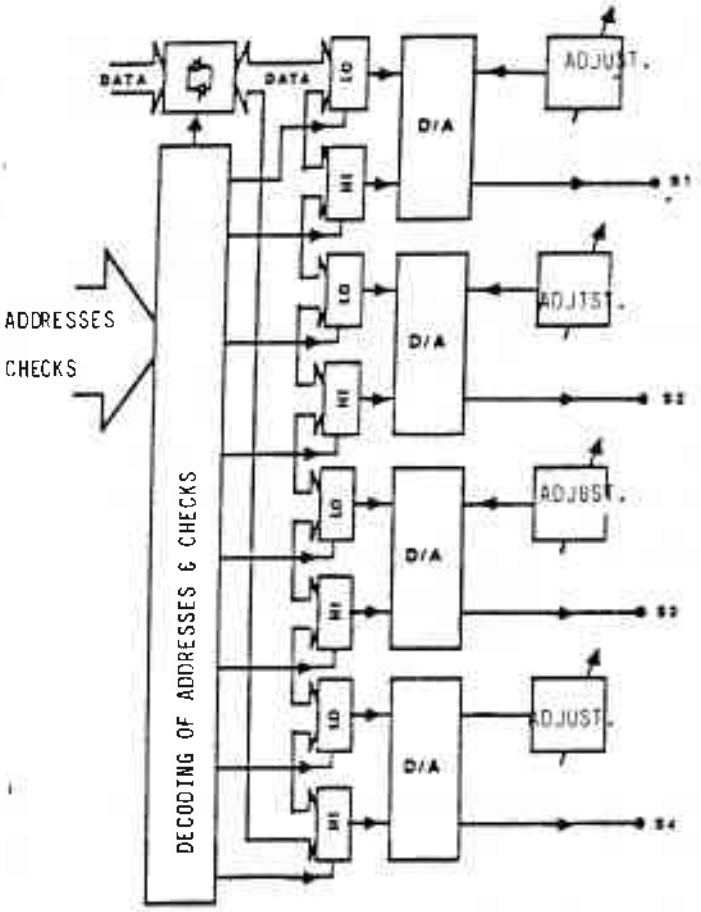
It performs analog-to-digital and digital-to-analog conversions on 12 bits.
2 analog outputs on DAC
8 multiplexed analog inputs



MIADA BOARD

3.4.7. MIDAC BOARD -(optional)

It performs digital-to-analog conversions.
4 addressable analog outputs.
MAXIMUM TWO CARDS



MIDAC BOARD

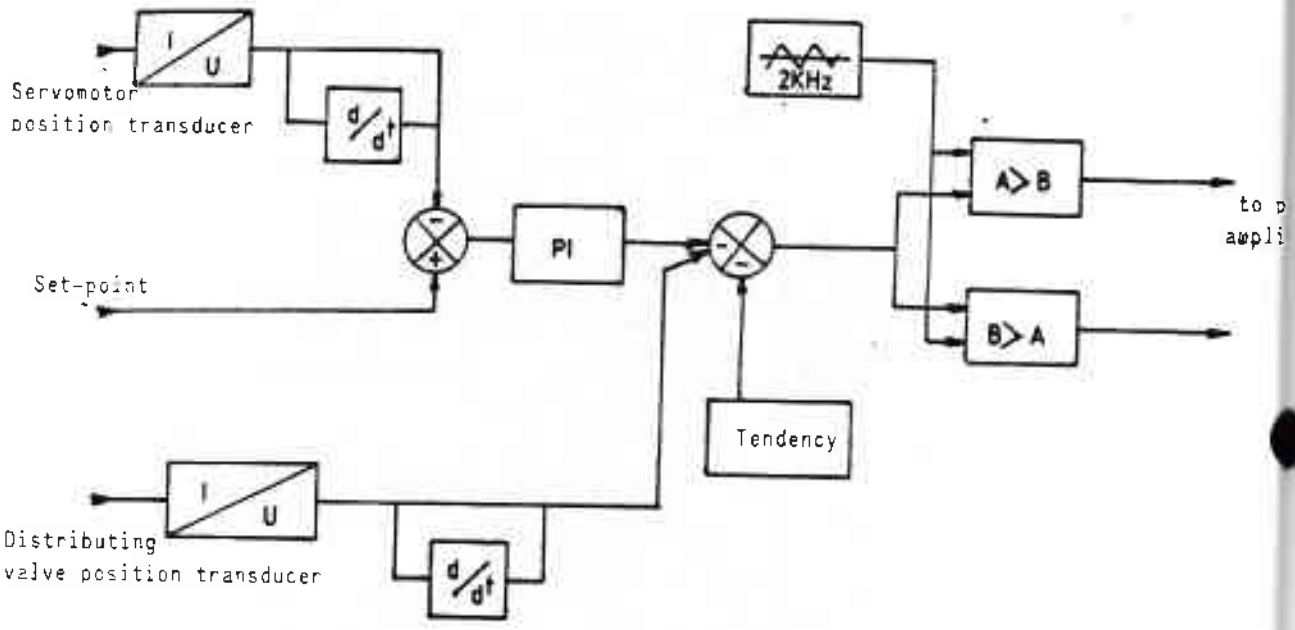
3.4.8. SIO BOARD - (optional)

- 2 channels for RS 422 serial communication
- Adjustable (separate) transmission speed
- data from CPU transmitted in serial form
- acquisition of outside data

This board is used for - information output to printer
- or remote keyboard

3.4.9. POSITIONER BOARD - PC POS

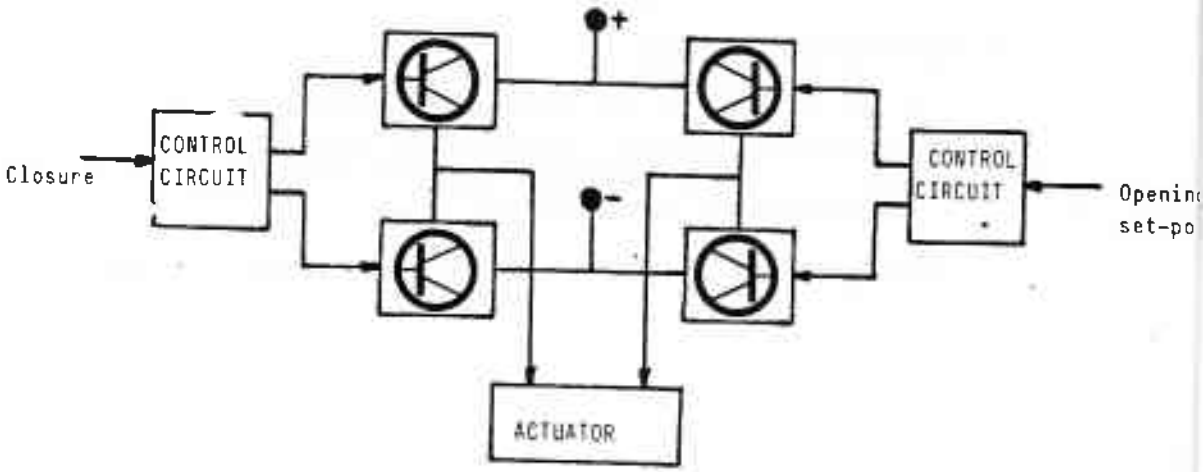
Analog circuit for PID control (proportional, integral, derivative) of servomotor position.
This circuit permits to control a power slicing amplifier constituted by a H-bridge.



This board is fitted only when a TR10 type actuator is provided in the HYDRAULIC system.

3.4.10. POWER BOARD - PC PUIS

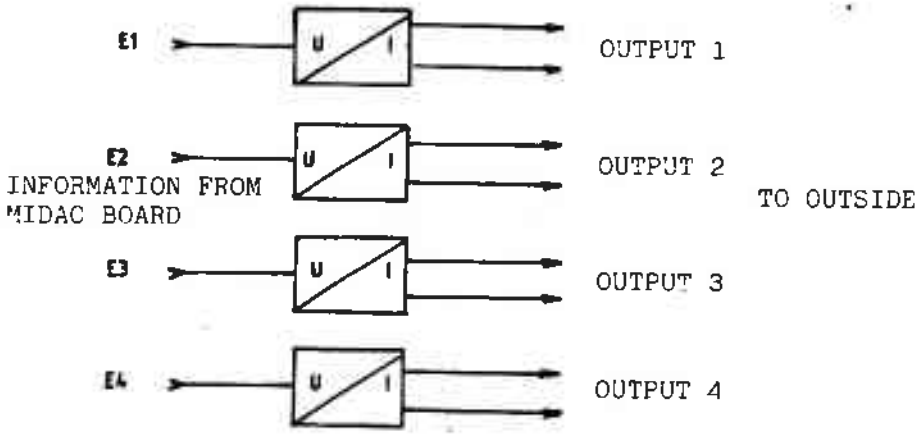
Power slicing amplifier of the H-bridge type. It permits to pilot a TR10 electrohydraulic actuator. Current flows through the actuator coil alternately in either direction depending on an opening or closure order being given.



This board is fitted only when the actuator in the HYDRAULIC system is of the TRIO type.

3.4.11. ANALOG OUTPUT BOARD- PC 376 (optional)

Four analog remote-indication channels are available on this circuit The cabinet-rack can be fitted with 2 PC 376 boards to give 8 analog outputs.

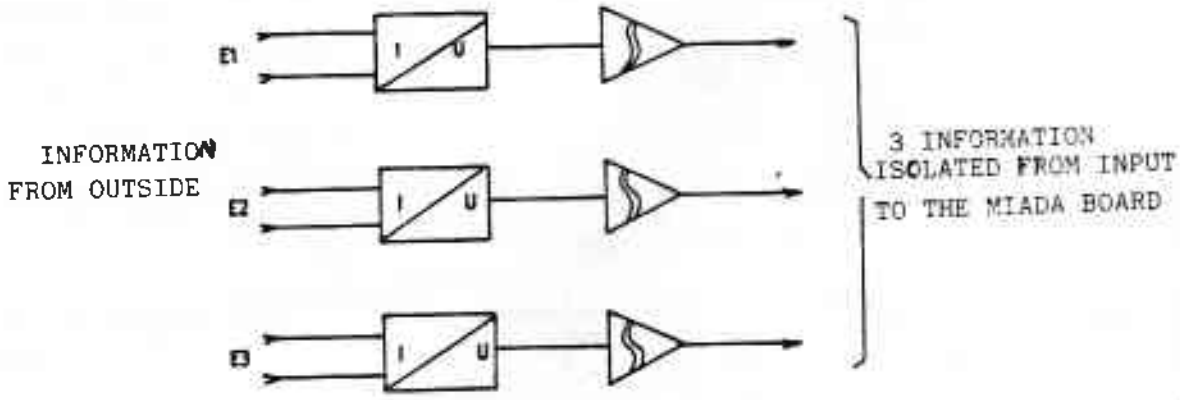


IMPORTANT

This board isnot galvanically-isolated.
For isolating the analog outputs, a special interface must be provided in lieu of the circuits n° 375 (OPTIONAL)
This interface is mounted outside the rack (see Sketch N2, mark 006 - Description of DIGIPID governor)

3.4.12. Galvanic isolation of analog inputs - PC 377

This INPUT board ensures galvanic isolation of 3 analog signals entering the governor.
The DIGIPID rack can be fitted with one board PC 377



Note : apart from analog output isolation, the special interface (sketch N2, mark 006) also includes 4 inputs of galvanically-isolated analog signals.
Board 377 is automatically omitted in the DIGIPID rack when the special interface is fitted.

3.4.13. Logic I/O BOARD -PC 402

This interface circuit comprises :

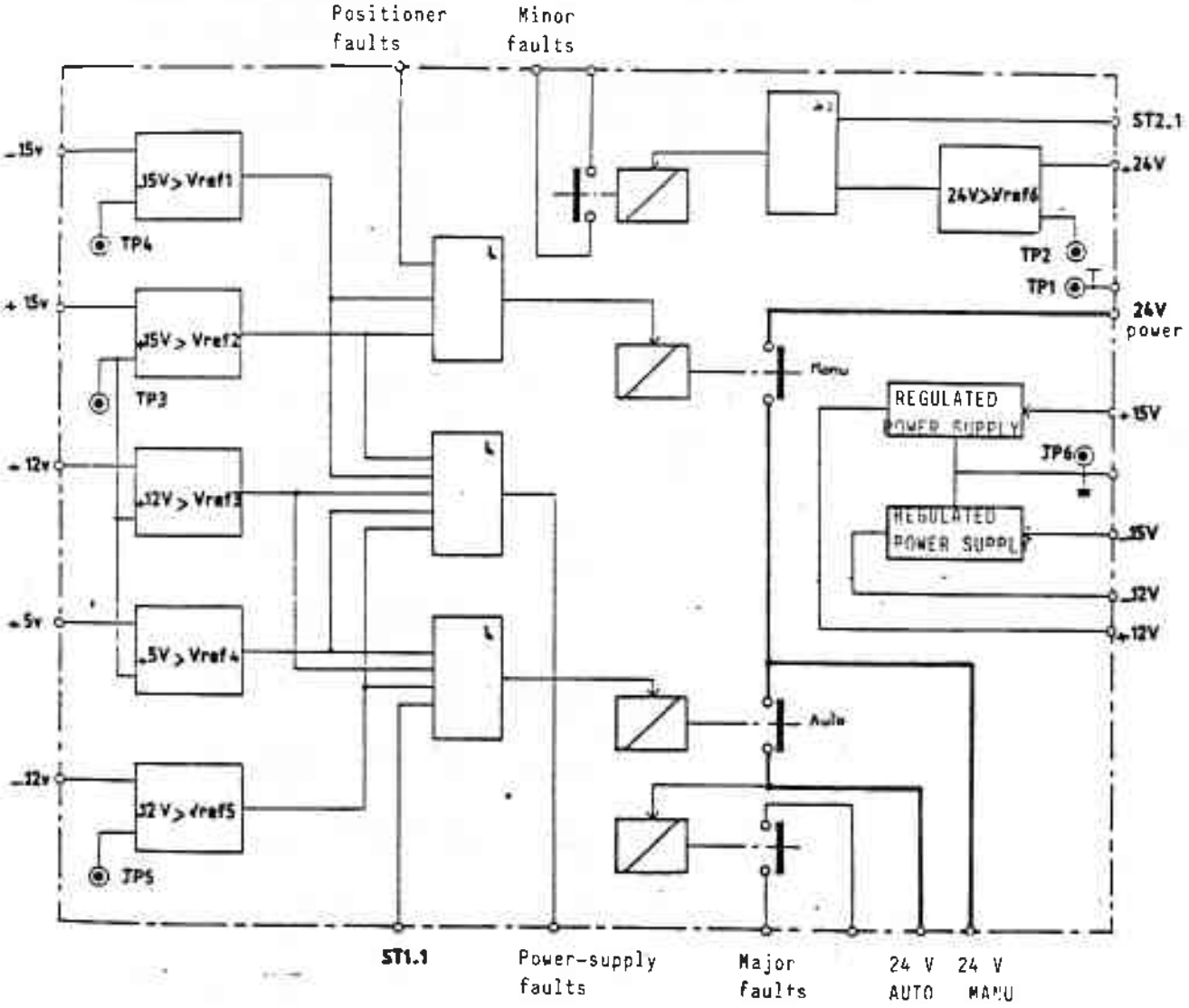
- 6 digital inputs
- 10 logic outputs

Through the use of jumpers, 2 additional inputs are made available by cancelling one output.
Up to 3 PC 402 boards can be fitted to the DIGIPID rack to obtain the required number of inputs-outputs.

3.4.14. Monitoring Board - PC 406

This board monitors internal voltages :
+ 24 V fault for u < 18 V
± 15 V valid for |u| > 14 V
± 12 V valid for |u| > 11.4 V
+ 5 V valid for u > 4.8 V

It also handles :
faults on regulating device position transducers
minor faults
major faults



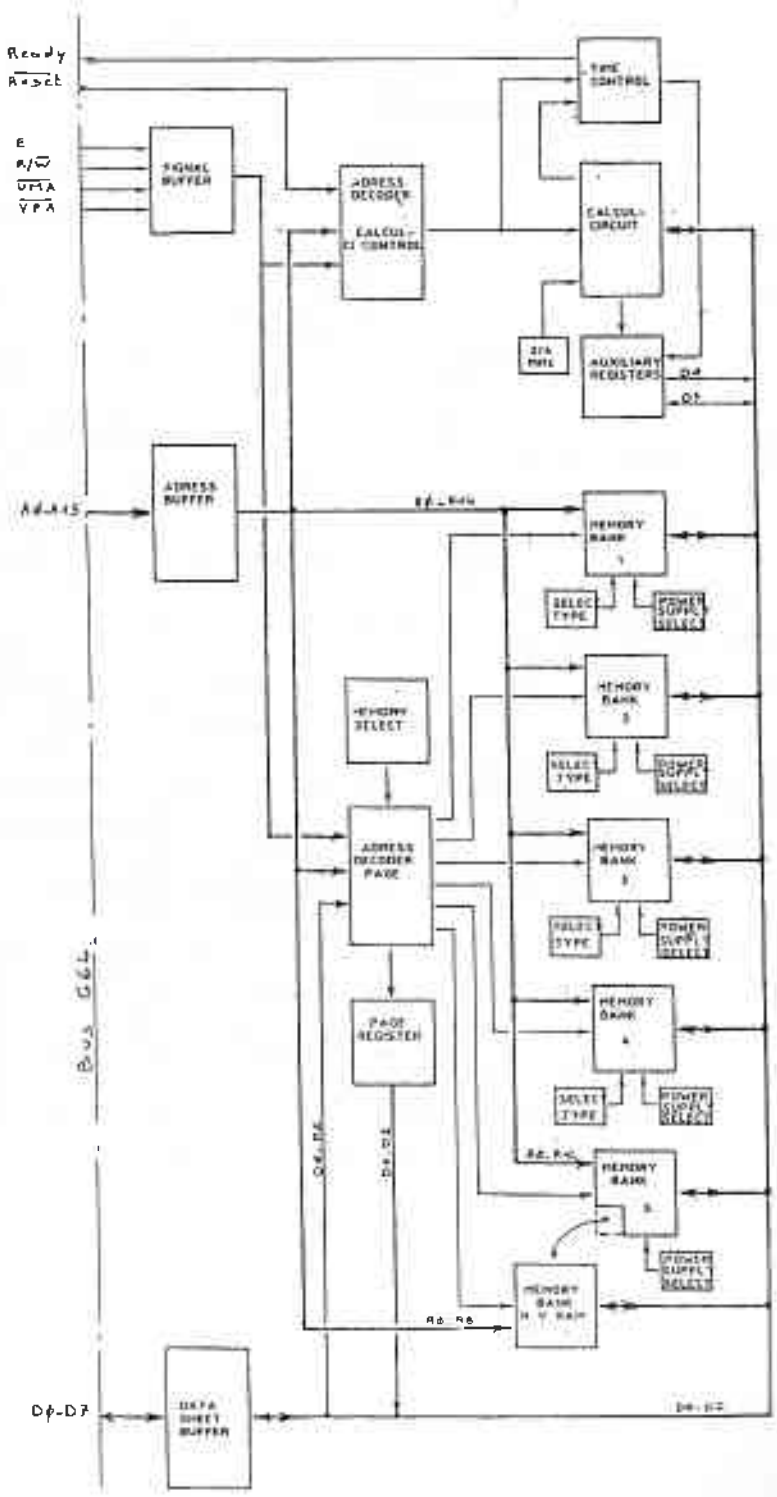
3.4.15. MPPA CI 460 CARD

It is used in 3 version for replacing MEM and EFS.CAL cards.

It offers a 136 K octets extended memory 4 x K 32 octets spread over in one page.

8 K octets separeted innespective of pages.

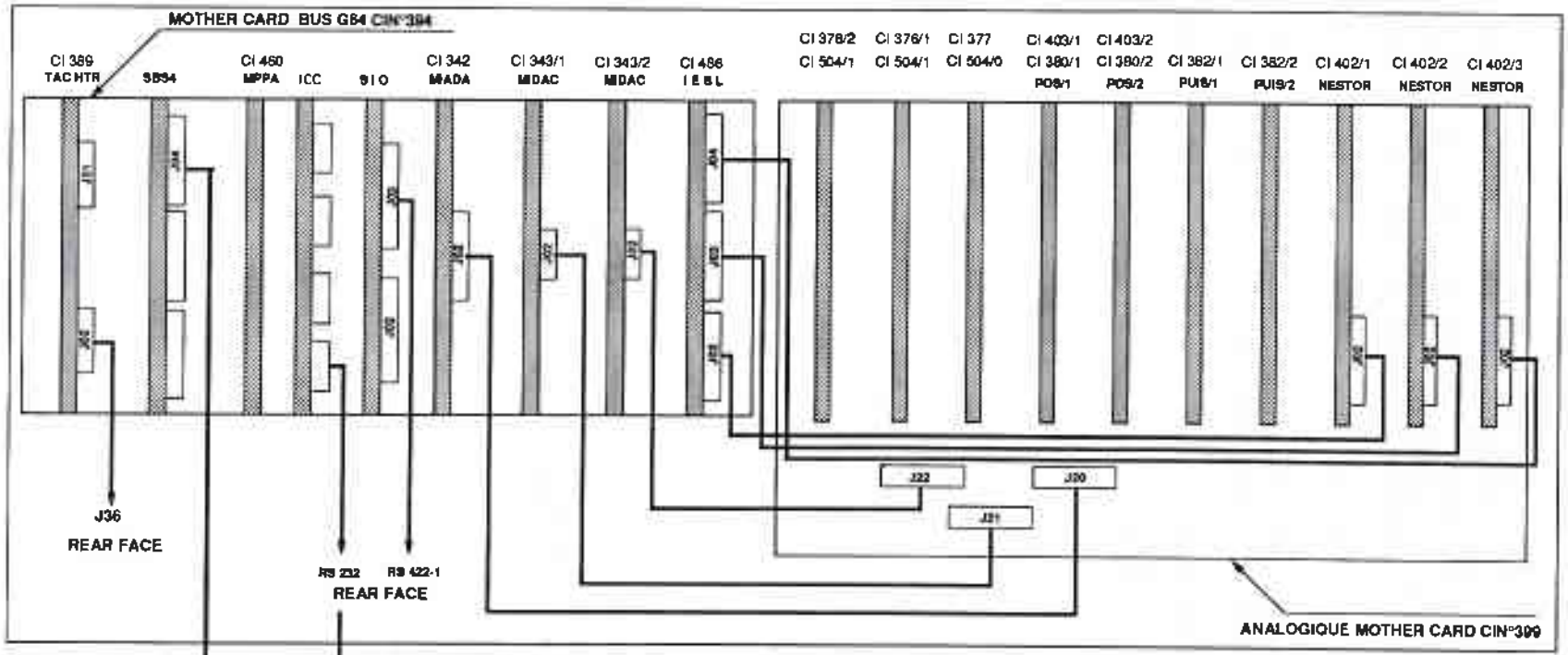
Functional DIAGRAM

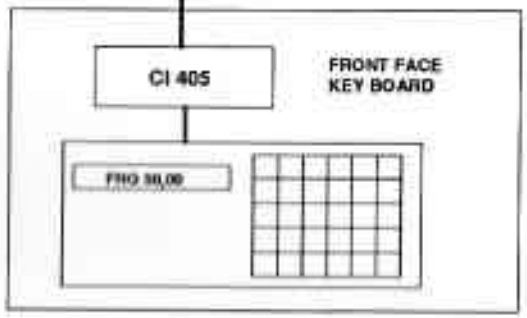


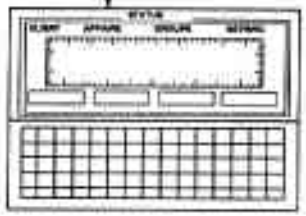
3.5. MOTHER-BOARDS

Two mother-boards are provided at the rear-part of the card-container for the digital sector (PC 394, mark F29, Sketch N5) and analog sector (PC 399, mark F32, sketch N5) respectively. Mother-board mark F29, of multilayer with intermediate mass plane construction, offers an excellent protection of low-level inputs against high-level signal outputs.

Another multilayer mother-board (PC 400, mark F56, sketch N5), secured to the DIGIPID rear face, bears connectors for outside connections.
It is linked to the analog mother-board through three flexible circuits (mark F05); this technology guarantees a high reliability of electrical internal connections.
Connection between mother-boards is made through wire-to-wire layers (see sketch N9)
Other electric connnections between connectors J35, J36 of the rear face and the mother-boards are made through conventional wiring (see sketch N10)
Strap J38 (mark F37, sketch N5) is used for dispatching power supplies from J35 to the various circuits.







NOTE : THERE IS NO TEST PROGRAM FOR THE CARD ICC

| | | |

FROM					TO	
	N° of connect	TYPE OF WIRE-LAYER	LENGTH			
CI 389 TAC-HTR	J02	10 / shielded	75cm		J36	REAR face
GES	P5 haut	20/ not shielded	40cm		J1	CI405 FRONT face
CI 342 MIADA.2	J02	20/ shielded	45cm		J20	CI 399 motherboard
GES SIO.1A		20/ not shielded	55cm			RS422.1 rear face
GES SIO.1A		20/ not shielded	60cm			RS4222 rear face
CI343/1 MIDAC	J02	10/ shielded	45cm		J21	CI399 motherboard
CI343/2 MIDAC	J02	10/ shielded	45cm		J22	CI 399 motherboard
CI486 IESL	J02	20/ not shielded	40cm		J02	CI 402/1 nestor.2
CI486 IESL	J03	20/ not shielded	45cm		J02	CI 402/2 nestor.2
CI486 IESL	J04	20/ not shielded	50cm		J02	CI402/3 nestor.2
KEYBOARD		25/ not shielded	15cm		J02	CI 405 Front face
CI 405 int RS232	J03	26/ not shielded	80cm		J02	CI 406 fault monitoring
CI 400 Motherboard rear face	J31	20/ not shielded	20 cm		J01	CI 406 fault monitoring

SERIE N° | PLAN SERIE 6654031 | CODE 0346121000 | ETUDE | OE | REP

DESSINE PAR | ECH

VERIFIE PAR

VISE PAR

DATE

NEYRPIC

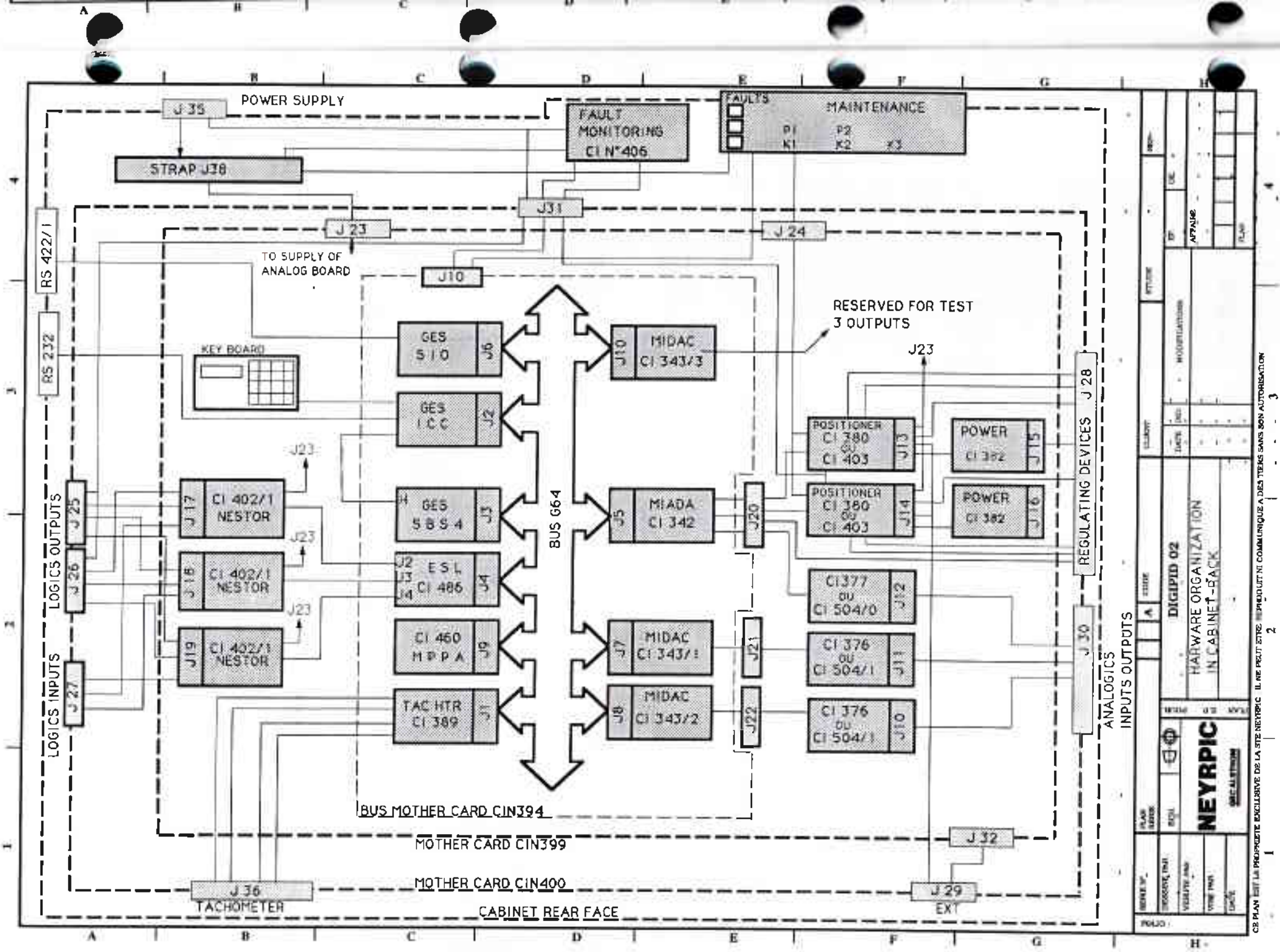
DIGIPID

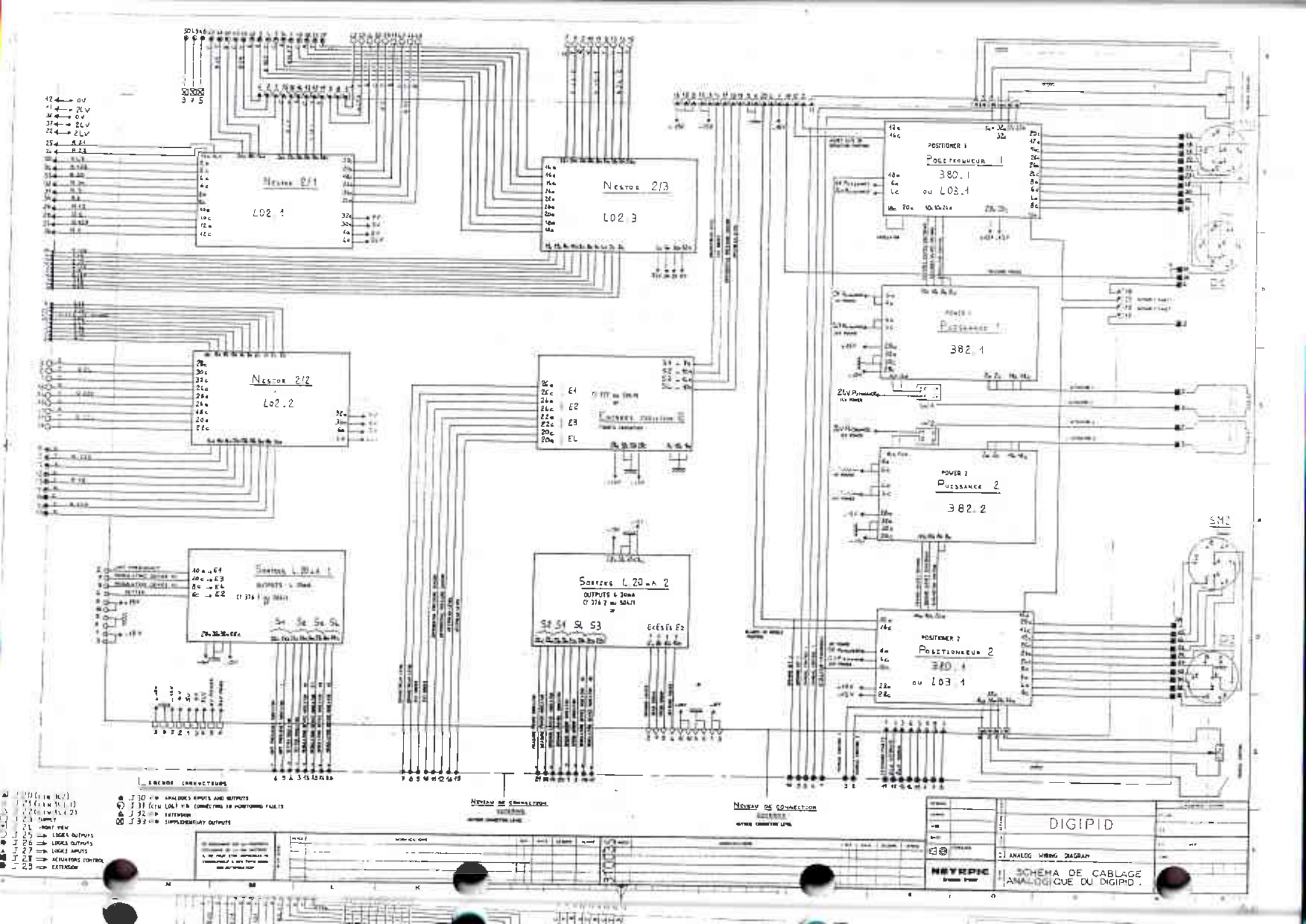
sketch 9 bis

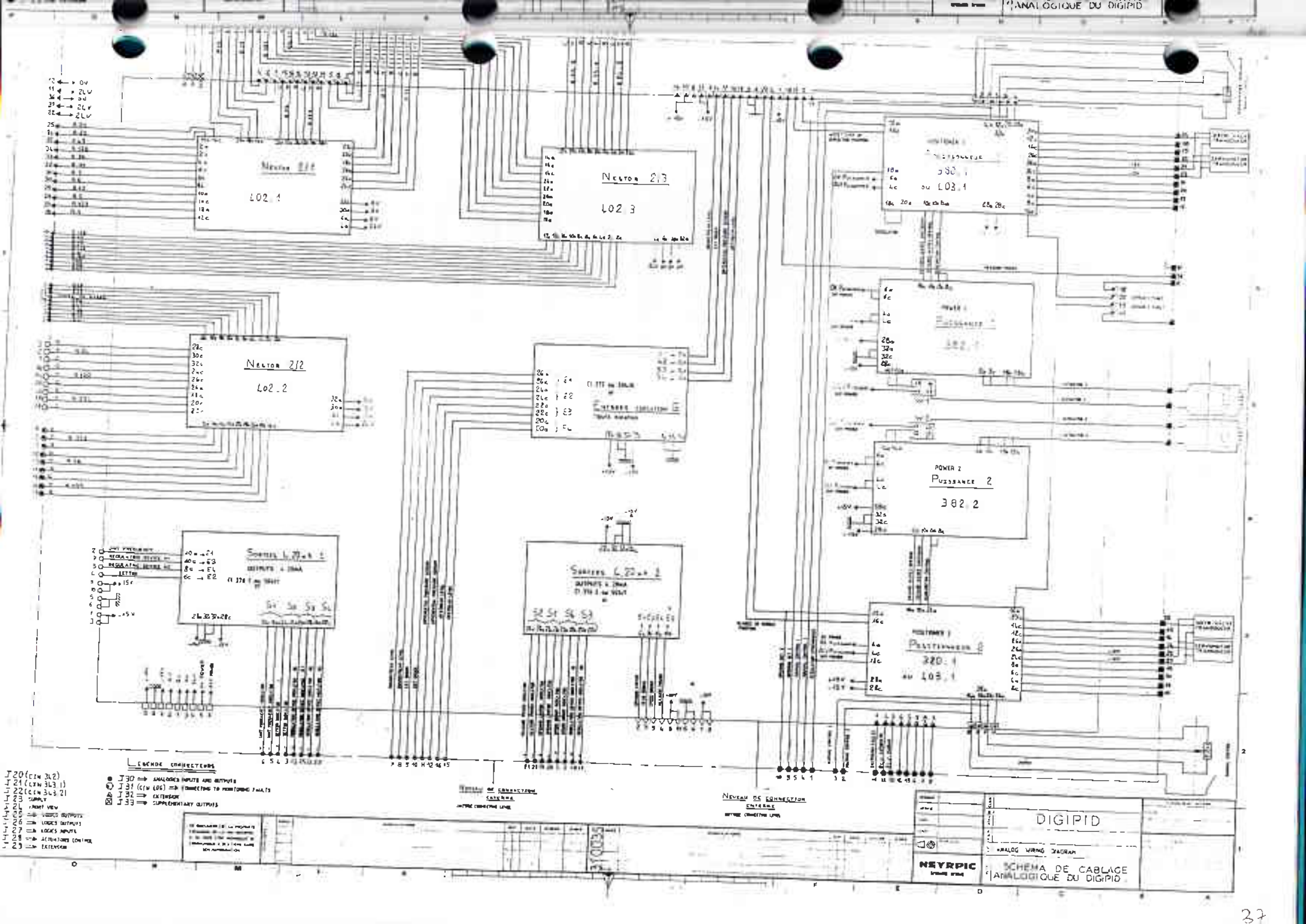
WIRING LAYERS

DATE | NO. | MODIFICATIONS

CE PLAN EST LA PROPRIETE EXCLUSIVE DE LA STE NEYRPIC. IL NE PEUT ETRE REPRODUIT NI COMMUNIQUE A DES TIERS SANS SON AUTORISATION


POWER SUPPLY
J 35
FAULT MONITORING CI N°406
FAULTS
MAINTENANCE
P1 P2
K1 K2 K3
STRAP J38
J31
J 23
J 24
TO SUPPLY OF ANALOG BOARD
J10
RS 422/1
RS 232
KEY BOARD
GES 510
J6
GES ICC
J2
GES 5854
J3
ESL CI 486
J4
CI 460 MPPA
J9
TAC HTR CI 389
J1
BUS G64
MIDAC CI 343/3
J10
MIADA CI 342
J5
MIDAC CI 343/1
J7
MIDAC CI 343/2
J8
RESERVED FOR TEST 3 OUTPUTS
J23
POSITIONER CI 380 OU CI 403
J13
POSITIONER CI 380 OU CI 403
J14
J20
POWER CI 382
J15
POWER CI 382
J16
CI377 OU CI 504/0
J12
CI 376 OU CI 504/1
J11
CI 376 OU CI 504/1
J10
J21
J22
REGULATING DEVICES J 28
J 30
ANALOGICS INPUTS OUTPUTS
LOGICS OUTPUTS
J 25
J 26
J 27
LOGICS INPUTS
J17 CI 402/1 NESTOR
J18 CI 402/1 NESTOR
J19 CI 402/1 NESTOR
J23
BUS MOTHER CARD CIN394
MOTHER CARD CIN399
MOTHER CARD CIN400
J 32
J 36 TACHOMETER
J 29 EXT
CABINET REAR FACE
DIGIPID 02
HARDWARE ORGANIZATION IN CABINET-RACK
NEYRPIC
CE PLAN EST LA PROPRIETE EXCLUSIVE DE LA STE NEYRPIC IL NE PEUT ETRE REPRODUIT NI COMMUNIQUE A DES TIERS SANS SON AUTORISATION


NESTOR 2/1
L02.1
NESTOR 2/3
L02.3
NESTOR 2/2
L02.2
POSITIONER 1
POSITIONNEUR 1
380.1
ou L03.1
POWER 1
PUISSANCE 1
382.1
POWER 2
PUISSANCE 2
382.2
POSITIONER 2
POSITIONNEUR 2
380.1
ou L03.1
SORTIES L 20 mA 1
OUTPUTS 4 20mA
SORTIES L 20 mA 2
OUTPUTS 4 20mA
ENTREES TOR
DIGIPID
ANALOG WIRING DIAGRAM
SCHEMA DE CABLAGE ANALOGIQUE DU DIGIPID.
SM2


NEYRPIC
DIGIPID
SCHEMA DE CABLAGE ANALOGIQUE DU DIGIPID
ANALOG WIRING DIAGRAM
NESTOR 2/1
L02.1
NESTOR 2/3
L02.3
NESTOR 2/2
L02.2
POWER 2
PUISSANCE 2
382.2
PUISSANCE 2
320.1
au L03.1
J20 (CON 3L2)
J21 (CON 3L3.1)
J22 (CON 3L3.2)
J30 ⇒ ANALOGICS INPUTS AND OUTPUTS
J31 (CON L06) ⇒ CONNECTING TO MONITORING PANELS
J32 ⇒ EXTENSION
J33 ⇒ SUPPLEMENTARY OUTPUTS

4. FUNCTIONS OF DIGIPID GOVERNOR

4.1. BASIC GOVERNOR

In the minimun configuration, the DIGIPID governor performs the following functions :

- Unit starting and rated-speed governing
- manual synchronization and connection to grid (i.e. the DIGIPID must be controlled by an outside unit : synchro-coupler)
- opening control of connected unit, with permanent speed droop adjustable from 0 to 10%; set-point adjustment by analog remote-setting or logic orders
- control of turbines with one regulating device (FRANCIS) (PUMP TURBINE)
- three information outputs in the form of dry contacts :
  . two programmable speed-limits
  . operation with opening-limit
- three speed droops values selected by outside order
- two adjustable gate-position polarizations controllable from the outside

and of course, all monitoring and safety functions :

- auto-test
- power supplies monitoring
- watchdog

In addition, the governor is fitted with a gate hand-control and a maintenance software for failure automatic diagnostic.

4.2. OPTIONS

Numerous options are available on the DIGIPID governor; the main options are described below :

4.2.1. KAPLAN-BULB turbines

- additional electrohydraulic positioner
- specific software for relationship between the two regulating devices versus the head ("surface" cam relationship).

../..

4.2.2. PELTON turbines

- one additional electrohydraulic positioner
- specific software for nozzle/deflector relationship

4.2.3. Multi-jet PELTON turbines

This option requires to use digital positioners.

1 positioner per needle.

4.2.4. Speed-increaser Bulb units

For this type of Bulb unit, a special relationship is required for the regulating devices.

- one additional electrohydraulic positioner
- specific software for blade/gate relationship

4.2.5. Power feedback

- electric active-power transducer and connecting devices
- associated logic inputs/outputs (opening/power control switching, power switches ...)
- power feedback software with power limitation in terms of the head

4.2.6. Dual feedback

This option is intended for plants where steadiness is critical (surge tank of too small sizes...) and combines power-feedback and opening-control.

- power transducer and connecting devices
- logic inputs/outputs
- dual feedback software with power limitation in terms of the head

4.2.7. Water level monitoring

Opening control in proportion with the difference between (upstream or downstream) water level and a constant set-point (adjustable through the keyboard)

- isolated analog level inputs
- level monitoring software

4.2.8. Discharge control

The set-point, with Unit connected to grid, is a mere opening set-point. Thanks to the deadband introduced into the tachometer, the Unit participates in primary adjustment only in case of large frequency deviation on the grid.

4.2.9. Automatic synchronization

Before connection, the Unit is brought to a speed equal to the grid synchronism speed with a programmable shift from -5% to +5%. Only the connection order must be given from the outside.

- grid tachometer
- logic input for manual/automatic synchronization selection
- quick automatic synchronization software

4.2.10. Automatic connection

With this option, the DIGIPID ensures Unit start-up, synchronization with shift, Unit/grid voltage equality checking and Unit/grid voltage shift measurement. It gives the connecting order when all conditions are met, with a phase-lead permitting "in-phase" connection (phase lead programmable by means of keyboard). For safety reasons, the connecting order is constituted by 2 serial logic inputs located on 2 different boards :

- grid tachometer
- logic inputs/outputs
- automatic connecting software

4.2.11. Remote controls and signalling

- control panel and linking cable
- serial communication board
- software

5 . MAIN CHARACTERISTICS AND PERFORMANCES

Tachometer inputs

- On Unit and grid voltage transformers :
  - . transformer-isolated inputs
  - . rated amplitude : Ao = $\frac{100}{\sqrt{3}}$ V, 100 V, 127 V, 220 V, 380 V rms single-phase
  - . minimum operating level : 1% Ao
  - . absorbed current : 10 mA rms max.
  - . frequency deadband : 10^{-4}
  - . crystal frequency reference : precision = 10^{-6}

Parameter setting range

- operating point : -10% to +10% of nominal frequency

- accelerometer	: Tn = 0 to 100 s	programmable by means of keyboard
- transient reaction time constant	: Td = 0 to 100 s	
- temporary speed droop or proportional gain	: bt = 0 to 100% ∞ to 0.1	
- permanent speed droop	: 0 to 10%	

Logic inputs : on photocouplers

- control by dry loop fed in 24 V d.c. by the governor

Logic outputs : by dry contacts

External load (or level, or opening) set-point

- input isolated by solid-state galvanic separator
- standard ratings :

0 – 10 mA
4 – 20 mA
} scale indicating Unit full opening

- load taking slope grading adjustable from 5 sec to 1275 sec steps by steps of 5 sec.

Opening limiter

- operating time adjustable from 10 sec to 500 sec steps by steps of 10 sec.

5.1. CONTROL OF REGULATING DEVICES

- Position adjustable from 0 to 100% opening
- Opening upon start-up : 0 to 100%
- Opening-decrease upon start-up : 0 to 100%
- Opening-decrease speed : 0 to 100% or rated speed

} adjustable by means of keyboard

- polarizations and pre-positioning : 0 to 100% (adjustable by means of keyboard)

5.2. GOVERNING CHARACTERISTICS

- Speed deadband : $ix \leq 2.10^{-4}$
- Control signal deadband : $ic < 2 \times 11^{-3}$

LIST OF PARAMETERS AVAILABLE FOR DISPLAY

WORDING	No.	DEFINITION	UNIT	OPTION
BP	0	Permanent speed droop,	%	
TN	1	Accelerometer time constant,	s	
N	2	Accelerometer gain,		
TD	4	Integrator time constant,	s	
BT	3	Temporary speed droop,	%	

LIST OF TYPICAL VALUES AVAILABLE FOR DISPLAY

WORDING	No.	DEFINITION	UNIT	OPTION
FGR	5	Unit frequency,	Hz	
FRS	6	Grid frequency,	Hz	
FRF	7	Reference frequency,	Hz	
DF	8	Frequency deviation,	%	
E	9	Accelerometer output,	%	
S	10	PID output,	%	
C	11	Setter output,	%	
W	12	Measured power,	%	RWN
LW	13	Power limitation,	%	RWN
CV	14	Gate setting,	%	F,KB,BX
CD	15	Deflector setting,	%	P
V	16	Gate position,	%	F,KB,BX
D	17	Deflector position,	%	P

../..

WORDING	No.	DEFINITION	UNIT	OPTION
CP	18	Blade setting,	%	KB,BX
CI	19	Pilot nozzle setting,	%	P
P	20	Blade position,	%	KB,BX
I	21	Nozzle position,	%	P
CSC	22	Output setting before blade/gate relationship and/or bias	%	
CPO	23	Blade setting before blade/gate relationship	%	KB
LOH	24	Opening limit versus head	%	NAV,NAM DELTAP
LO1	25	Opening limit controlled from outside	%	
LON	26	Opening limit versus downstream level	%	NAV
LO	27	Actual opening limit	%	
NAV	28	Downstream level	m	NAV
NAM	28	Upstream level	m	NAM
CHU	30	Head	m	NAV+NAM DELTAP
GL	31	Upper limit, integral action	%	
PL	32	Lower limit, integral action	%	
OEE	33	Analog outside order (testing)	%	
CVO	34	Gate setting	%	
LFP	35	Closing limit blades	%	
CP1	36	Blade setting	%	
CIO	37	Nozzle setting	%	
CI1	38	Nozzle setting	%	
S1	39	To put in memory	%	
EW	40	Power variance	%	
EL	41	Limit variance	%	
OEI	42			
TM	43			
M	44			
BTD	45			
TDD	46			
ED	47			
SD	48	Reserved		
GLD	49			
PLD	50			
EPS	51			
COMP	52			
GDEF	53			
TOD	54			
TFD	55			
EF	56	Frequency variance	%	
EP	57	Power variance	%	

LIST OF OPTIONS

WORDING	MEANING
FRANCIS	FRANCIS turbine
KAPLAN/BULB	KAPLAN or conventional BULB turbine
STEP-UP BULB	BULB turbine with step-up gear
PELTON	PELTON turbine
LOWER LEVEL	Downstream level transducer
UPPER LEVEL	Upstream level transducer
DIFF. PRESSURE	Differential pressure transducer on runner
LOAD FEEDBACK	Power and/or level regulation
LOAD ADAPT. (1)	Adaptation of power parameters
BLADE ADAPT. (1)	Adaptation of blade/nozzle position parameters
VAR. SPEED DROOP	Variable speed droop in terms of frequency deviation
AUTO. COUPLING	Automatic coupling to grid
CONDIT./B. OR N. (2)	Conditioning in relation to blades or to nozzles
FLOW	Flow regulation
R10	Outside control of opening limits upon start-up
UNIT TACHO. FAULT	Gate closure upon Unit tachometer fault (Unit connected to grid)
EXT ORDER 4.20 mA	

(1) In the lack of both options, the adaptation is made in relation to gate or deflector position

(2) In the lack of this option, the conditioning is made in relation to gates or deflectors

LIST OF CONSTANTS

WORDING	No.	DEFINITION	UNIT	VALUE	OPTION
BP0	0	Permanent speed droop when R12 = 0 and R112 = 0	%	0 - 10	
BP1	1	Permanent speed droop when R12 = 1 and R112 = 0	%	0 - 10	
BP2	2	Permanent speed droop when R112 = 1	%	0 - 10	
TNO1	3)		s	0 - 100	
NO1	4)	PID parameters when		1 - 10	
BTO1	5)	R28 = 0 and R128 = 0	%	0 - 1000	
TDO1	6)		s	0 - 100	
TNO2	7)		s	0 - 100	
NO2	8)	PID parameters when		1 - 10	
TBO2	9)	R28 = 1 and R128 = 0	%	0 - 1000	
TDO2	10)		s	0 - 100	
TNO3	11)		s	0 - 100	
NO3	12)	PID parameters when		1 - 10	
BTO3	13)	R128 = 1	%	0 - 1000	
TDO3	14)		s	0 - 100	
I	15	Tachometer deadband	%	0 - 2.5	
SV1	16	Speed limit n° 1	%	0 - 300	
SV2	17	Speed limit n° 2	%	0 - 300	
SV3	18	Speed limit n° 3	%	0 - 300	
AJUF	19	Adjustment of reference frequency	0/000	-128/+128	
CHF0	20	Load-frequency rising time when R23 = 0	s	5 - 1275	
CHF1	21	Load-frequency rising time when R23 = 1	s	5 - 1275	

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WORDING	No.	DEFINITION	UNIT	VALUE	OPTION
TEST	22	Testing parameters : TEST=0 : normal operation TEST=1 : introduction of outside order downstream of accelerometer TEST=2 : introduction of outside order upstream of accelerometer		0.1 or 2	
VRAB	23	Speed of opening-limit decrease (changing from LOD to LOR)	%	0 - 100	
LOD	24	Opening-limit upon start-up	%	0 - 100	
LOR	25	Opening-limit after decrease (speed VRAB)	%	0 - 100	
LOP1	26)	Opening limit biases (not used)	%	0 - 100	
LOP2	27)		%	0 - 100	
LOP3	28)		%	0 - 100	
LOP4	29)		%	0 - 100	
LOP5	30)		%	0 - 100	
LWF	31	Fixed power limit	%	0 - 100	RWN
BW1	32	Power limit n° 1	%	0 - 100	RWN
BW2	33	Power limit n° 2	%	0 - 100	RWN
CNAM	34	Upstream level setting	m	0-max.level	RWN & NAM
CNAV	35	Downstream level setting	m	0-max.level	RWN & NAM
HR	36	Reference head	m	0-max.head	DELTAP
HN	37	Nominal head	m	0-max.head	DELTAP,NAM NAV
NAMR	38	Upstream reference level	m	0-max.level	NAM
NAMN	39	Nominal upstream level	m	0-max.level	NAM
NAVR	40	Downstream reference level	m	0-max.level	NAV
NAVN	41	Nominal downstream level	m	0-max.level	NAV

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WORDING	No.	DEFINITION	UNIT	VALUE	OPTION
PCP 0	42	Blade setting bias when R25 = 1	%	0-100	KB,BX (1)
PCP 1	43	Blade setting bias when R26 = 1	%	0-100	KB,BX (1)
PCP 2	44	Blade setting bias	%	0-100	KB,BX (1)
PCP 0	45	Gate setting bias When R126=1 and R127=0	%	0-100	KB,BX,F
PCV 1	46	Gate setting bias when R126=1 and R127=1	%	0-100	KB,BX,F
GLI	47	Shift to automatic synchro-nization	%	-5 +5	
TAC	48	Lead time for coupling	ms	0-1000	COUPLING
TLO	49	Time constant of opening limiter		10. 500	
EPS					
GDEF					
OEI		RESERVE			
DFOE					
DEFW					

(1) When several inputs R25, R26, R27 = 1, the respective biases add.